REVIEW OF EFFECTIVE METHODS OF INTEGRATING MAN-MADE SLOPES AND RETAINING WALLS (PARTICULARLY FOR ROADSIDE SLOPES) INTO THEIR SURROUNDINGS

GEO REPORT No. 116

Halcrow China Ltd

GEOTECHNICAL ENGINEERING OFFICE

CIVIL ENGINEERING DEPARTMENT

THE GOVERNMENT OF THE HONG KONG SPECIAL ADMINISTRATIVE REGION

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PREFACE

In keeping with our policy of releasing information which may be of general interest to the geotechnical profession and the public, we make available selected internal reports in a series of publications termed the GEO Report series. A charge is made to cover the cost of printing.

The Geotechnical Engineering Office also publishes guidance documents as GEO Publications. These publications and the GEO Reports may be obtained from the Government's Information Services Department. Information on how to purchase these documents is given on the last page of this report.

R.K.S. Chan
Head, Geotechnical Engineering Office
October 2001

EXPLANATORY NOTE

This GEO Report consists of Volume 1 of the consultancy study report on methods of integrating man-made slopes and retaining walls into their surroundings. The study was carried out by Halcrow China Ltd for the Geotechnical Engineering Office under Agreement No. GEO 9/98. The study report is in 2 volumes - Volume 1 is the guidance document and Volume 2 contains the results of some 200 slopes inspections carried out during the course of the study. Readers may view Volume 2 of the study report at the Civil Engineering Library, Civil Engineering Department.

FOREWORD

This report presents a review of and guidance for the aesthetic design of man-made slopes in Hong Kong, particularly roadside slopes. The guidance presented in this report is based on the findings of reviews of local and international practice into the reduction of visual impact of slopes, as well as accepted good landscape practice. The report is in 2 volumes. This is Volume 1 and is the guidance document. Volume 2 contains the results of some 200 slope inspections carried out during the course of the local review.

The guidance is intended for use by geotechnical engineers, and is not meant to be a complete coverage of aesthetic slope design. Emphasis is placed on subject matter that is particular to Hong Kong.

The report was produced for the Geotechnical Engineering Office (GEO), Civil Engineering Department (CED) under Agreement No. GEO 9/98 by Halcrow China Ltd in collaboration with landscape specialists, Urbis Ltd in Hong Kong and Chris Blandford Associates in the United Kingdom for overseas landscape input. The report was prepared under the auspices of a Steering Committee formed of representatives from the following departments within the Government of the Hong Kong Special Administrative Region: Highways Department, Agriculture, Fisheries and Conservation Department and GEO of CED.

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EXECUTIVE SUMMARY

Hong Kong has a large number of man-made slopes, which form an increasingly visible element in the landscape. In recent years media attention has been directed at the visual appearance of man-made slopes. As a result, GEO commissioned a study (Agreement No. 9/98) to provide guidance on methods of integrating slopes into their surroundings.

The objective of the study was to produce guidelines to reduce the visual impact of slopes to enable them to be integrated into their surroundings. This was to be achieved by incorporating accepted good landscape practice into the findings of a review of local and international practice into methods of reducing the visual impact of slopes. The local review incorporated current design practice, inspection of some 200 slopes, and surveys and interviews with the industry. The international review comprised a literature review of slope landscape techniques used to reduce visual impact elsewhere in the world, that might be applicable to Hong Kong.

This report is set up as a guidance document taking the reader through the various stages of the design process. This includes a substantial section on the different slope landscape treatment methods used in Hong Kong. This is accompanied by tables that provide an evaluation of a wide range of slope treatment techniques.

A review of the current slope design process in Hong Kong identified the dominant slope forms and treatments. Slope form is strongly influenced by the Geotechnical Manual for Slopes (GCO, 1984) and the most common slope treatment, based on the findings of the slope inspections, was sprayed concrete (or shotcrete). The inspections did however indicate that the recently completed slopes had better landscape treatment than the older slopes. A survey of practitioners within the industry showed a greater awareness of landscape on slopes, with many engineering firms routinely using landscape architects. However, it must be appreciated that the majority of the inventory of man-made slopes in Hong Kong have been shotcreted and it will take some time before a perceptible overall improvement can be achieved.

The report promotes the need to integrate engineering and landscape professionals within the design process from the outset. This is considered as the best opportunity to achieve a balanced design that will satisfy both the engineering and aesthetic requirements. Comments received from landscape architects note the generally late involvement of landscape architects within the design process.

The report includes general principles of aesthetic design illustrated with examples of slopes in Hong Kong showing good and bad practice. The main aesthetic considerations for rock, soil and mixed rock and soil slopes are discussed. How engineering design, such as geometry and drainage, affects the appearance of a slope and how it can be used to reduce the visual impact is discussed with examples.

The international review examined published literature on alternative design practice seldom or not commonly used in Hong Kong and which may be applicable. The review identified bio-engineering and “green wall” techniques as possible alternatives. Bio-engineering was investigated in Hong Kong in the 1980s but has failed to develop since. The review also included a summary of papers presented at the recent Asian bio-engineering conference. A large number of the techniques presented at the conference were generally low-tech and low-cost with many examples from developing countries in Asia. The

applicability of these techniques to Hong Kong would need to be established through trialling.

The landscape treatments reviewed are based on the treatments identified from the inspection of local slopes and information on proprietary products provided by the manufacturers or their agents. Altogether, about 50 treatments are included, which are grouped by treatment type, namely soft, hard and mixed. For each type, applications and considerations on their use are presented. The individual treatment types are evaluated based on the findings of the inspections.

Soft slope treatment types include vegetative treatments only; these were the least common in the review accounting for 15% of all slopes inspected. Aesthetically they are considered the most successful. Slope angles ranged up to about 45° and there were few signs of engineering problems, except where lack of maintenance resulted in vegetation encroachment into drainage channels. The most aesthetically pleasing and ecologically sound finished slopes were judged to be a result of a combination of grass hydroseeding and pit planting techniques.

Hard slope treatments are non-vegetative treatments, and account for 26% of slopes inspected. This mainly included retaining walls and hard surfaced slopes. Aesthetically, the results varied. In particular, sprayed concrete slopes had few endearing visual features. Sprayed concrete with colour pigment was considered to blend into its surroundings reasonably successfully when viewed from long-range. Stained and smooth featureless slope surfaces were seen as visually intrusive.

Mixed slope treatments are a combination of vegetative cover and different hard surfacing, and comprised 59% of inspected slopes. This included some 20 individual treatments, such as vegetated rock slopes, soil nailing with hydroseeding, use of erosion control mats and geogrids. Notable treatments that were visually successful and sustained vegetation at a steep gradient included soil nailing and geogrid reinforced slopes. Grillages were also identified as offering potential for vegetation establishment on steep slopes when combined with soil nails.

The main conclusions based on the findings of the study are as follows:

(a) Feedback received from engineers indicates that the existing landscape guidance is considered insufficient.

(b) Landscape objectives are not clearly stated in the design process, providing no mechanism against which to verify the finished landscaping product.

(c) A large number of treatments are available in Hong Kong but only a few are used in practice.

(d) From the inspections, sprayed concrete was found on 50% of the slopes inspected.

(e) Several alternative treatments for vegetating steep soil slopes exist and should be trialled in Hong Kong.

(f) Improvement in landscape treatment was noted on slopes completed in the last few years.

CONTENTS

1. INTRODUCTION

1.1 Purpose and Scope

Man-made slopes and retaining walls form part of the built environment of Hong Kong and, like the rest of the built environment, their appearance affects people's lives on a day to day basis. Development in the steep hilly terrain of Hong Kong has resulted in a large number of man-made slope features in a relatively small area and as such these features form a notable visual element in the Hong Kong landscape.

The oppressive visual appearance of some man-made slopes and retaining walls has been the subject of increasing media attention. Much of the attention has been directed at the use of hard slope surfacing, typically sprayed concrete. In appreciation of these concerns, the Geotechnical Engineering Office (GEO) of the Government of the Hong Kong Special Administrative Region (SAR) instigated a study to review methods of improving the visual quality of man-made slope features, particularly roadside slopes.

In December 1998, GEO appointed Halcrow China Ltd to undertake a study under GEO Agreement No. GEO 9/98 entitled "Review of Effective Methods of Integrating Man-made Slopes and Retaining Walls (Particularly for Roadside Slopes) into Their Surroundings".

The overall purpose of the study is that, after review of local and international practice and products and detailed local case study, a set of guidelines and principles is developed for the SAR to improve the visual integration of man-made slopes and retaining walls into their surroundings. See Appendix A for the Brief.

Particular emphasis is given to the visual integration of roadside slopes into their surroundings and the guidelines, in a summary form, can be found in the Highway Slope Manual (GEO, 2000).

The contents of this report are based on accepted good landscape practice and on the findings of the following key activities:

(a) A comprehensive review of local slope practice, which included a review of design guidelines and solutions, and the inspection of some 200 slopes territory-wide.

(b) An opinion survey of local geotechnical engineers and landscape architects to assess professional awareness of the issue of visual quality of slopes.

(c) Comprehensive review of international slope practice, which comprised a literature review of international publications.

(d) Case study review of a number of local slope designs that included interviews with landscape architects, geotechnical engineers and landscape contractors.

(e) A review of products and proprietary techniques used locally and overseas that could be used to lessen the visual impact of slopes. This includes information on cost and performance as well as maintenance requirements.

The selection of the 200 local slopes for the review was based on the need to examine the full range of treatments from those used commonly to those used only occasionally. A list of different slope treatments was compiled from the Consultant's experience and from consultation with involved government departments, consultants and contractors. The target was to find a minimum of three examples of each slope treatment. The selection was inevitably biased towards the more common treatments but this had the merit that the commonest problems were addressed.

The selection was limited by the need for:

(1) Slopes to be within government land.

(2) A reasonable amount of information about the slope to exist.

(3) The slope had to have been completed for a sufficient time for the effect of the landscape treatment to be apparent.

To this list was added some well known slopes which had been the subject of media attention.

The selection of the Case Studies was from the 200 slopes as chosen above and with the addition of several slopes jointly suggested by the Steering Committee. The Case Studies slopes were selected to examine the particular role of the landscape architect at each stage of the design process and the effectiveness of the landscape treatment both in an engineering sense and visually. It was important in the Case Studies selection that the slopeworks were relatively recent to facilitate the tracing of records and individuals involved. To speed up the interview process, interviews were limited to the parties involved in this project and in LPM works.

1.2 The Structure and Use of This Report

This report presents a review of and guidance for the aesthetic design of man-made slopes in Hong Kong, particularly roadside slopes. The guidance given in this report is based on the findings of the reviews and recommended practice and is principally intended for use by geotechnical engineers engaged in slope works.

The report is set up as a guidance document with the following sections: current slope design practice, the planning and design process, planning considerations, design considerations and landscape treatments, which includes an evaluation of the treatments used in Hong Kong.

Alternative slope design practices not normally used in Hong Kong, such as bio-engineering, which can reduce the visual impact of man-made slopes are also reviewed.

The records and photographs of the some 200 slope inspections undertaken as part of the local review are included in Volume 2. Each record gives an evaluation of the slope treatment on that slope in terms of engineering and aesthetic performance.

The effectiveness of the various slope treatment types is assessed using the findings of the review of local slopes, case study review and information provided by product manufacturers. The applicability of slope landscape treatments and practices for Hong Kong is assessed and included as recommendations.

Integrating slopes into surroundings more successfully is largely a matter of applying known techniques and principles to actual projects. This report summarises the current approach and identifies where this could be improved through the collation or expansion of existing databases, and improvements to the administrative procedures in slope restoration projects.

2. OUTLINE REVIEW OF CURRENT SLOPE DESIGN PRACTICE IN HONG KONG

Within Hong Kong, slope design practice largely follows the guidance given in the Geotechnical Manual for Slopes (Geotechnical Control Office (GCO), 1984) and Geoguide 1 (GEO, 1993). The slope manual contains guidance on the geotechnical design of slopes as well as on types of slope covers, drainage and slope form and shape applicable to the local conditions. The manual has had a strong influence on the appearance of man-made slopes adopted by local designers. This is reflected in the findings of the inspections of local slopes, where it was found in practice that a limited number of slope forms dominated.

Over the past years, the increasing use of hard surface slope covers has resulted in the publication of several documents providing guidance on the visual impact of slopes, this includes for example Works Branch Technical Circular No. 25/93, (WBTC, 1993), GEO (1997, 1999a, 1999b). These provide guidance on limiting the use of sprayed concrete and provide information on the use of vegetation on slopes.

Most engineering consultants contacted reported that they generally now seek professional landscape advice for slope work. Consultants engaged on the Government's Landslip Preventive Measures (LPM) Programme are contractually bound to engage a landscape architect for the work. It was however found that in most case studies reviewed (Appendix B) landscape issues were considered too late in the slope design process to be fully effective with little effective liaison between the engineer and landscape architect.

The inspections of local slopes found little evidence of an integrated engineered-landscape slope design solution and no examples of landscape considerations clearly influencing the engineering design. In certain cases, where the geotechnical considerations were found to be complex, no consideration was given to aesthetic landscaping at all (e.g. landslide site at Ching Cheung Road, see Volume 2, Appendix C, Study No. 322).

The inspections did indicate that recently completed slopes generally have better landscape treatment. This is viewed by the authors to be related to an increasing awareness of landscape considerations within the geotechnical profession. Older slopes generally have little landscape treatment, though current work on improving their visual quality has resulted in the introduction of planting berms and in some cases, sprayed concrete has been coloured (e.g. Wong Nai Chung Gap Road, see Volume 2, Appendix C, Study No. 388) and Plate 12(b).

The slope inspections found that a wide range of slope treatments has been used in Hong Kong (Table 1). Certain treatments are dominant with, for example, sprayed concrete on about 50% of the slopes inspected and on 65% of cut slopes (Table 1). Where innovative slope treatments were used, there are only a few examples found (e.g. Creat Toyo-Mulching at Smithfield Road Extension, see Volume 2, Appendix D, Study No. 81). Certain treatments used elsewhere in the world, such as bio-engineering have not been widely used in Hong Kong.

To gain a better appreciation of the use of landscape in slope design practice an opinion survey was carried out among 56 geotechnical engineers involved in LPM works in 12 of the larger engineering consultant firms and GEO (Appendix C). The results of the survey are based on a limited number and therefore may not be representative.

A similar survey was carried out amongst landscape architects from 15 landscape consultant firms and Government Departments. The results again may not be representative. The results show that most respondents considered that the poor visual quality of some slopes was mainly attributed to landscape not being given sufficient priority in the design process.

3. OVERVIEW OF PLANNING AND DESIGN PROCESS

The planning and design of a slope should not only take into account the stability, cost and maintenance requirements but should also consider the aesthetic aspects of the slope. The aesthetic design should aim to complement the landscape and visual character of the area and to improve the overall visual quality of its setting. The designer should consider the need for advice from landscape professionals.

In general, to achieve a balanced slope design that will satisfy both the engineering and aesthetic requirements, geotechnical engineers and landscape professionals should work together as a design team from the inception of the project to develop an integrated design solution. Integration of landscape considerations within the various stages of the slope design process is illustrated conceptually in Figure 1.

Conflicts may arise between the engineering and landscape requirements. In such cases, safety considerations are paramount.

4. PLANNING CONSIDERATIONS

4.1 General

In accordance with the principle of complementing the landscape and visual character of an area, the need for significant slope works should be reduced or, wherever possible, eradicated by early planning and good design (Department of Transport, 1992). Ideally, routes for new roads or sites for development that minimise the impact on the landform will obviously reduce the need for expenditure on slope works and maintenance, and reduce the visual and environmental impact. However, due to the terrain and development pressures in

Hong Kong, this ideal solution is very rare where major new construction projects are proposed.

For slope works that are part of major projects it may be necessary to carry out a landscape and visual impact assessment of the proposed slopes as part of an environmental impact assessment under the Environmental Impact Assessment Ordinance. The need for an impact assessment depends on whether the project is classified as a 'designated project', that is a project that may have an adverse impact on the environment under the Ordinance (Environmental Protection Department (EPD), 1997 and 1998).

Upgrading of existing slopes would not normally be considered as a designated project. However, where the upgrading includes earthworks, and this is wholly or partly within a Country Park, conservation area, cultural heritage site, green belt or a site of special scientific interest then the upgrading may be classified as a designated project (EPD, 1998). It should be noted that the words "urban" and "rural" are used in this report in their usual descriptive context. They do not imply maintenance jurisdiction. As a matter of course, where slope works encroach upon any of the areas designated above, particular attention should be given to the quality of the visual finish of the slope (Chapter 10 of Hong Kong Planning Standards and Guidelines (Planning Department, 1994)).

Where full landscape and visual impact studies are required this should be undertaken in accordance with the Technical Memorandum on Environmental Impact Assessment Process (EPD, 1997), and will generally require the use of landscape professionals. Account should be taken of programming and funding arrangements for mitigation measures developed as part of the impact assessment process. The costs to be allocated to the visual design should be determined by considering the expected improvements in the visual impact brought about by possible mitigation measures and the costs associated with the mitigation measures. The cost of visual mitigation may range up to 20% of the total slope works costs.

4.2 Visual Importance

As a guide to the extent of landscape treatment that may be required for general slope works the designer should undertake, as part of the planning stage, a brief assessment of the visual importance of the slope. This will make aware to the designer for example, whether a landscape professional should be engaged.

Visual importance can be defined as a function of the number of people (receptors) who will see the slope each day and their sensitivity to that view (Plate 1). The sensitivity of receptors is influenced by:

(a) the value of existing views i.e. the proximity and context of the viewer,

(b) the degree to which the existing view would be affected, and

(c) the activity in which they are engaged.

As a general guide, those who view from residential homes are considered to have high sensitivity because the attractiveness, or otherwise, of the view would have a notable effect on a resident's general quality of life and home environment. Views from workplaces are considered to have relatively less sensitivity because they are in areas where visual outlook plays a less important role in the quality of the working environment.

The value of views of people engaged in outdoor leisure pursuits depends on the type of recreational activity. Those taking a stroll in a park or sightseeing, for example, would value their views much more highly compared to, say, football players. The sensitivity of the people who view the slope from public thoroughfares, depends on the speed and frequency of travel. Generally, the slower the speed of travel and the more continuous the viewing experience, then the higher the sensitivity. Note should be made of repeated views such as for commuters.

Proximity to the slope and angle of view, and the proportion of the view that the proposed slope will occupy are factors that should also be taken into consideration in the evaluation of visual sensitivity. Where a view is only partially occupied by a slope then the level of visual sensitivity should be reduced.

The number of people who view a slope should also be taken into consideration when determining the visual importance of a slope. For example, a slope adjacent to tower blocks would likely be viewed by very many people compared to a slope along a minor road, which would be seen by only a few people.

Other factors that the designer needs to consider when proportioning the likely landscape costs to a design include features of special landscape interest such as fung shui, cultural and historical features. Designers should also have regard to the planning and development framework, with additional care taken for slopes in areas of noted landscape, conservation, recreational or cultural venues.

Tables 2, 3 and 4 are used to indicate the likely visual importance. The costs to be allocated to the visual design aspects of a slope should be considered in proportion to its visual importance. Much greater attention should be given for slopes assessed as having a high visual importance than those having a low visual importance. Depending on the visual importance of the slope, the landscape costs may range up to 20% of the total slope works costs. It should be borne in mind that Tables 2, 3 and 4 are generalities. They do not take account of slopes in designated areas e.g. Country Parks. The requirement for slopes in these areas to be regarded as 'special cases' has already been addressed in Section 4.1. Similarily, slopes with a long previous history of complaints should be assigned very high/high visual importance regardless of numbers or sensitivity of viewers.

4.3 Ecological Considerations

The creation of an ecologically sustainable vegetation cover is a key objective in any planting works. Naturally occurring vegetation types in Hong Kong include secondary woodland, tall scrub or open grassland. Planting to simulate these habitat types that is based on sound ecological principles will contribute to the wider environment and usually provide the best visual fit with the surrounding landscape. It also offers the best way to minimise long term maintenance commitments, as ornamental planting will require constant maintenance to achieve its desired effects.

Examination of natural vegetation existing on the slope feature and surrounding natural hill slopes can be a guide to ecologically sound planting proposals.

4.4 Site Supervision

The need for comprehensive supervision of the landscape aspects of slope treatment works by appropriately qualified staff is vital to their success. Frequently, landscape works come late in the construction process and at a time when cost and programming considerations require the works to be undertaken in a short period of time.

Allowance should be made for the employment of suitably qualified landscape/horticultural site staff within Resident Site Staff (RSS) budgets, so that expert supervision can be provided for the key elements of the work such as the clearance and protection of existing vegetation, soiling, planting and maintenance works. It is important for the RSS team to have an understanding of the potential impact of all of the various engineering works undertaken by the Contractor on existing vegetation and future planting works so that potential conflicts can be identified and resolved without compromising the landscape or engineering objectives of the project. Provision of landscape site staff might be on a part time basis for small numbers of features, or full time for large packages of works.

4.5 Maintenance

The importance of maintenance for the long-term safety of slopes and retaining walls cannot be over emphasized. The lack of maintenance of slopes and retaining walls is the major contributory factor to many landslips in Hong Kong.

For slopes in Government land, the maintenance responsibility for landscape works is currently defined in WBTC 18/94 and further refined in the schedule attached to PELB/WBTC 24/94 which defines the authorities for tree felling approval. These two documents do not comprehensively define maintenance responsibility and in some cases there is doubt and dispute about maintenance responsibility between government departments. The matter is being addressed by Works Bureau (formerly Works Branch) and it is anticipated that on agreement of concerned authorities, it will be formally presented as amendments to the schedule attached to WBTC 24/94. For purposes of this report it is vital that the general principle of WBTC 18/94 is adhered to viz. “The general principle to be followed is for the relevant departments to agree what will be included and who will maintain it, early in the design development.”

On allocated Government land responsibility rests with the land user, e.g. Housing Authority for Public Housing Estates. Similarly maintenance responsibility lies with the owner on private lots.

In practice and from the findings of the slope inspections, it has been observed that little or no horticultural maintenance is undertaken after handover of completed landscape works on a slope. This is possibly due to several factors, such as, the size and number of the slopes involved, the technical difficulty of getting safe access, and the lack of awareness of the need and specific funds for doing so.

Maintenance is a key issue in the improvement of slopes through planting. From discussion with involved staff from RSD/USD and AFD it is noted that there are insufficient resources in any Department to fulfil the maintenance commitments required, and as a result no effective maintenance of planting on slopes is undertaken. This is being addressed through a review of WBTC 18/94 (Works Branch, 1994b).

Designers should seek to minimise maintenance wherever possible and to ensure the provision of adequate and safe access for maintenance. However, it should be clearly understood that all landscape works require maintenance which must be thoroughly and rigorously undertaken if the objectives of the landscape design are to be realised. At the outset, designers should identify the level of maintenance that will be required to achieve their landscape and engineering objectives (GEO, 1995a) and ensure the maintenance agency is made aware of and is committed to undertaking the required operations.

5. DESIGN CONSIDERATIONS

5.1 Aesthetic Design – General Principles

In order to achieve a successful aesthetic solution and to integrate the slope effectively into its environment a slope design should reflect the characteristics of the surrounding environment. Characteristics such as landform, colours and textures of surrounding vegetation and rock can be simulated in the final design. The accepted general aesthetic principles are:

(a) that the landscape design should maintain as far as possible a natural appearance,

(b) where, for geotechnical reasons or other reasons it is not possible to maintain a natural appearance, then the landscape design should aim towards an appearance that fits with its surroundings, and

(c) in certain circumstances, where the surroundings are particularly suitable, an architectural (artificial) design or treatment may be appropriate.

In most cases, it will not be possible to find a solution that fulfils all the aesthetic objectives, and the solution that best fulfils them should be chosen. In such cases, it is essential that a record is kept of why design decisions were taken, so that this can be accounted for in the event of future public comment.

5.1.1 Slope Geometry and Broad Scale Landform Considerations

An attempt should always be made to integrate the geometrical slope design with the landforms of the surrounding topography within the limitations of land constraints and safety requirements. Straight, engineered slope profiles look unnatural when seen in the wider landscape setting and should be avoided. If space permits, slope edges should be ‘rolled’ back into the surrounding landform (Figure 2). If possible, a more natural curvilinear profile slope surface should be adopted. Slopes that include some element of ridgeline, skyline or horizon when seen from key viewpoints need careful treatment. In particular, artificial or rigid geometric shapes and profiles should be avoided as these will be obvious in contrast to natural topography and landscape.

5.1.2 Natural Solution Versus Artificial Solution

People generally find a ‘natural’ solution (be it rock or vegetation) preferable to an engineered one. A natural solution will almost always ‘fit’ appropriately into any location (Plate 2).

There are however, situations when a well designed and executed engineering solution (e.g. retaining wall) can be as attractive and appropriate as a ‘natural’ solution. However, to execute an engineered solution well, requires considerably more thought and offers more potential for error, in terms of its appearance.

As a general rule, hard-engineered solutions will tend to be more suitable for urban locations than for rural ones.

5.1.3 Existing Slopes

There is essentially no difference in the aesthetic design approach used for new and existing slopes. Upgrading works do, however, provide an opportunity to change or adapt an existing design to achieve a better “fit” into the surrounding environment. The scope to do so may be limited by site constraints that may for example prevent any significant alteration to the slope profile. In these situations, upgrading works need to be adapted to the existing slope form and surrounding environment (Plates 3a and 3b). Slope treatments that are appropriate for existing slopes and that can contribute to the greening of the environment include for example, retention of existing vegetation, slope surface planting pits, berm and toe planters, street trees, see Section 7.4.3.

Care should be taken to ensure that an acceptable level of slope stability as given in the Geotechnical Manual for Slopes (GCO, 1984) is maintained where it is intended to replace an impermeable surface cover on a slope by vegetation.

5.1.4 Cultural Considerations

It is important to consider the implications of roadside slope works on ‘fung shui’ issues. In addition to the presence of grave sites, worship huts and other cultural artefacts, designers should be aware that woodland blocks and trees, and some natural topographic features such as ridge lines, distinctive outcrops of rock and water courses can have distinct fung shui associations. Fung shui woodland for instance is commonly found around traditional village settlements and grave sites. The local District Office will be able to give direction on how to identify and evaluate fung shui features, and the procedures that should be followed in consulting local residents if features have unavoidably to be disturbed.

5.1.5 Retention of Existing Vegetation

The preservation of existing vegetation is controlled by WBTC 24/94 (Works Branch, 1994a) which identifies the authority and procedure for applications to fell, transplant, prune or affect existing trees in any way.

As a rule, trees should be retained wherever possible. Where a tree needs to be felled, designers should demonstrate a genuine need to do so, including the examination of alternative (and possible more complex and costly) engineering schemes. Where technical justification can be provided for the felling of a tree, applications shall be made to the relevant authorities for permission in accordance with the WBTC 24/94 (Works Branch, 1994a). No works should be undertaken prior to receipt of written approval.

The retention of existing vegetation is a key landscape mitigation measure. Wherever possible engineering works should be designed so that existing trees can be retained in their existing position. As most tree roots are in the surface layer of the soil within the spread of the crown, this area of ground has to be retained undisturbed as well as the trunk and canopy of the tree. Any disturbance of the ground may adversely affect the tree roots.

In certain cases only part of a tree's crown or root system might be affected. Tree surgery on retained trees in newly constructed or modified slopes will enable trees to adapt to the new and changed setting. Without tree surgery, trees may become unstable in their new, possibly more exposed setting (See Chapter 6 of Tree Planting and Maintenance in Hong Kong (SILTG, 1991)). Where the disturbed and severed portion does not exceed a third of the whole, the tree will likely survive and efforts should be made to retain the tree. Structural support may need to be provided for the following 12 to 18 months to allow new roots to grow. Corresponding thinning of the crown may also be required.

Where ground levels have to be raised around a tree, so long as this does not exceed an average depth of about one metre, it may be possible to retain the tree with 'root over-filling'. Over-fill material within the area of the tree's crown spread should be a no-fines aggregate, to allow the free movement of water and oxygen to the roots below.

Where trees can be retained in position, but the surface of the slope has to be hard paved, tree rings should be provided. Although standard details exist for tree rings (CED, 1994), designs should be co-ordinated with the hard surface treatment. The size of tree rings should be determined by the size of the tree trunk, and allowing a further 200 mm diameter for the future growth of the tree. Where roots have surface rooting patterns, the form of the ring should be adjusted, and on no account should roots be cut to accommodate standard designs.

Existing 'wall trees' (i.e. trees growing on a wall, such as the *Ficus microcarpa* shown in Plate 3a) have extensive aerial, surface and sub-surface rooting systems. They are particularly sensitive to disturbance, and should only be retained in their entirety. Skin walls and buttress features have been successfully used in the treatment of old masonry walls, to allow retention of existing wall trees (Section 7.4.3(16)).

Where existing vegetation and trees are to be cleared, every care should be taken to protect and conserve surrounding vegetation which is to be retained. For the avoidance of doubt, it is recommended that at the outset of the works all trees and other vegetation to be retained within the site boundary be clearly marked.

5.1.6 The Aesthetics of Slope Design

The following aesthetic considerations should be taken into account when designing the appearance of slopes.

(1) Unity and Coherence. The design of a slope should be both clear and visually understandable by a viewer (Plates 4a and 4b). Solutions which involve simple combinations of materials and features, in a regular rhythm or pattern are most intelligible to viewers. Conversely, designs which involve unrelated groupings of different features of differing types and characteristics, will tend to lack any sense of unity or purpose and will therefore be confusing to viewers. Natural patterns of rock and vegetation achieve coherence and unity by very large numbers of repetitions of a single coherent pattern (for example leaf or rock texture) on a very small scale.

(2) Proportion and Scale. The design of a slope should take account of the principle of proportion, that is, the appropriateness of the size of one part of an object to that of another part (Plates 5a and 5b). Elements of a slope should be proportionate both to the surrounding landform and to each other. For example, the facing units of a retaining wall should be of a scale appropriate to the size of the wall and to its other features. As a general rule, larger units should be used below, supporting smaller units above.

(3) Pattern and Texture. The patterns and textures of a slope should be appropriate both to its setting and to the distance from which it will be viewed (Plate 6). Pattern creates visual interest and can reduce the apparent size of a slope by breaking it up visually. The natural texture of vegetation suits rural locations whilst harder textures are more appropriate to urban areas. Obviously, a pattern which is to be viewed from a great distance or at a high speed will need to employ units of a larger size than one which is to be seen close up or at low speed.

(4) Rhythm and Complexity. In landscapes where there are strong patterns and textures, simple, uniform slope treatments will tend to stand out and can be rather monotonous. In most situations, a low level of complexity in the visual appearance of a slope will be desirable, whether it be derived from patterns of vegetation or from other features designed into the slope. Complexity of composition is particularly appealing if it employs uniform intervals, thus creating a regular rhythm (Plate 7).

(5) Colour and Albedo. Colours used on slopes should be chosen so that they respond to, and complement colours elsewhere in the landscape (Plate 8). Attempts to simulate colours identical to those of the surrounding landscape are rarely successful and the failure to simulate corresponding texture and pattern simply makes them stand out. In particular, man-made greens invariably look unnatural in the landscape. Instead one should

use complementary, rather than identical colours. Dark browns and reds blend in particularly well with natural landscape. Designers should also aim to reduce ‘albedo’, or reflectivity so that slopes blend into the landscape rather than standing out. For this reason, untreated sprayed concrete slopes are to be avoided.

5.2 Aesthetic Design Considerations and Slope Types

5.2.1 Rock Slopes

Existing rock in Hong Kong typically has an attractive natural colour and texture which are usually complementary to the surrounding landscape. Weathering tends to soften and enhance this appearance. Rock should be retained in the finished surface of a slope wherever possible.

From the survey of landscape practitioners it is noted that the exposure of natural rock surfaces without the use of spray concrete/rock bolts/wire mesh is considered to be aesthetically pleasing.

Where rock can be left in position, designers should seek to express the natural characteristic and appearance. Blasting using pre-splitting techniques often produces unnaturally sharp and regular lines, and angular edges and the presence of numerous drill holes gives rock an unnatural appearance. Large even rock faces also create an artificial impression. In creating a new rock face, designers should seek to replicate the size, proportion and geometry of a naturally occurring rock face. Ideally small-scale, multifaceted surfaces of varying angles and sizes, possibly with pockets large enough to support some planting should be created to create a more attractive naturalistic appearance (e.g. see Appendix B, Turret Hill Ex-Quarry at Shatin and Volume 2, Appendix D, Study No. 397). In this case well controlled blasting has created an aesthetically pleasing effect.

Naturally occurring boulders are also a great natural asset, and should be retained where possible. However, any splitting or the construction of large scale concrete structures to retain them in place is usually unsightly and negates the visual benefit of retaining the boulders, although artificial supports are visually considerably more attractive than sprayed concrete or other artificial surfaces.

In choosing the means of securing rock faces, designers should note that smaller scale artificial elements such as wire mesh and rock bolts blend in visually far more easily than large-scale features such as grillages (Section 7.4.3(4)) and buttresses (Section 7.3.3(10)).

5.2.2 Soil Slopes

The aesthetic design of soil slopes is generally considerably easier than rock or mixed slopes. In nearly all instances, it should be possible to establish vegetation on soil slopes.

In assessing alternative options for treating soil slopes, designers should seek to retain existing soil, and introduce soil wherever possible to allow vegetation to grow. Details of typical treatments are given in Section 7.2.3.

5.2.3 Mixed Soil and Rock Slopes

In many situations in Hong Kong slopes are formed partly of rock and partly of soil and these tend to be the most difficult to treat as they suffer from poor rooting conditions for plants and potential instability from loose rock material.

Where possible, designers should seek to retain and express the natural rock and establish planting in the soil that can be retained. Successful treatment in this way tends to form the most naturalistic and visually attractive slopes.

5.3 Engineering Design Affecting Aesthetic Appearance

5.3.1 Slope Geometry

In conventional design practice, slope geometry adopted for cut or fill slopes comprises a linear slope profile, planar on plan, separated at regular vertical intervals by horizontal berms. This conventional geometry is unnatural when compared to the surrounding landforms and is considered visually intrusive and, as far as possible, should be avoided. The use of more natural, curvilinear slope geometry is considered more visually pleasing. Contoured slope geometry comprises a linear profile but is curvilinear on plan. Landform slope geometry, which mimics the surrounding landform, is curvilinear in profile and on plan (Shor & Gray, 1995), see Figure 3. There are few true examples of landform slope geometry in Hong Kong.

Where berms are considered necessary, they give an opportunity for the construction of planters, which can support trees, climbers or trailing plants (Plate 9). However, this potential benefit should be weighed against the rather artificial character that straight lines of planting of this type could create. Varying the location, spacing and width of berms can help to mitigate this artificial look and create a more natural apparance. Where berm planters are used the need to provide water irrigation systems (e.g. southern approach to Ting Kau bridge, Shek O Quarry), requirements for access for maintenance and for inspection must be borne in mind.

5.3.2 Slope Infrastructure

Slope infrastructure, such as access stairs, drainage channels, maintenance berms, catchpits and sandtraps should be designed to reduce their visual impact on the slope, see for example GEO (1993b). Consideration should be given to placement of slope infrastructure in visually unobtrusive locations within the slope, such as the placement of access stairs along the perimeter of the slope. The slope infrastructure should also be co-ordinated into the overall visual design of the slope to contribute to the compositional rhythm and pattern rather than simply intruding. Plates 10a and 10b are examples of the “brutalist” architecture which dominates many of Hong Kong’s slope drainage layouts.

Slope drainage networks that are not carefully integrated into the overall visual design can result in unsightly linear features within the slope. If possible, the drainage network should be an integral part of the visual slope design, rather than a superimposed unnatural regular network of channels. The use of screening, sympathetic colouration of channels or the use of a more naturalistic drainage network should be considered (Figure 3). In Plate 10c, a more naturalistic drainage pattern has been effected but the opportunity to integrate this into the overall slope has been lost by the use of stark white concrete. The effect on the drainage network of adopting a natural drainage arrangement must be evaluated to ensure hydraulic performance and maintenance requirements are satisfied.

The use of pigmented concrete in the construction of drainage channels can significantly reduce the visual impact of a regular pattern of drainage networks on engineered slopes. Step channels and U-channels can be very visually intrusive, particularly in the first few years before the vegetation in surrounding areas grows sufficiently high to screen them. Use of pigments to tone with adjacent rock features can considerably improve the visual impression of a new slope. The recently completed slopes above Shek O Quarry are a good example of this technique (Plate 11a).

Drainage outfall structures, such as catchpits, and sandtraps into which slope drainage discharges at the toe of slope, need to be sympathetically placed and visually integrated into the scene. All too often, outfall structures are given no landscape treatment and intrude into the streetscape (Plate 10a), such that pedestrians are required to walk around them. Recessing of these outfall features into the slope and colouring them would reduce their visual impact.

Plate 11b provides an example of integration of drainage into the slope by the use of local stone for cladding the concrete. The example is from UK.

6. ALTERNATIVE DESIGN PRACTICES

6.1 General

An international review of alternative design practices which may be applicable to Hong Kong, and which may reduce the visual impact of slopes was undertaken. The review comprised a comprehensive literature review, largely focused on current international practice and emerging standards and innovative techniques most appropriate to Hong Kong. The principal findings of the review are that:

(a) Soil slopes offer the best opportunities for ‘natural’ solutions. Bio-engineering techniques are becoming increasingly used internationally as their structural properties and aesthetic advantages are realised.

(b) There is little international experience to draw upon for the treatment of very steep and high slopes which has not already been tried or is under consideration in Hong Kong. “Green Walls” offer considerable potential for the treatment of moderate height slopes in visually conspicuous locations.

6.2 Bio-engineering

Bio-engineering is generally considered as “the use of living vegetation, either along or in conjunction with civil engineering structures and non-living plant material, to reduce shallow-seated instability and erosion on slopes" (Department of Roads, 1991). The technique of using vegetation to stabilise slopes has increased dramatically in the last 30 years, such that it is now the 'preferred' solution in many countries world-wide for minor slope stabilisation and control of erosion problems. During the 1980s, such techniques were trialled in Hong Kong with ranging degrees of success (Greenway, 1989). Despite considerable developments in these techniques, bio-engineering is not yet commonly used in Hong Kong. Where vegetation is used in Hong Kong it is primarily on aesthetic grounds.

It is generally accepted that vegetation provides a beneficial role in stabilising slopes but because the interaction of plant and soil is imprecisely known it is not routinely possible to quantify its engineering role. Typical bio-engineering practice is to ensure that the slope is stable in terms of routine stability theory, ignoring any beneficial effects from vegetation. The vegetation effect then amounts to the addition of an extra margin of safety, and is a way of reducing slope maintenance or repair.

There are numerous examples of theoretical slope stability models that demonstrate the potential reinforcement effect of roots within the soil mass (CIRIA, 1990). However, it is recognised that there is still a lack of understanding of root architecture and soil-root interaction (Wu et al, 1999). Until this is better understood, the reinforcing effect of plant roots is likely to remain excluded from routine stability calculations. It is however, generally accepted that root action, in most cases, does provide a beneficial binding affect particularly at shallow depths in the soil. However the reinforcing effect and long term reliability of bio-engineering techniques are difficult to quantify and this may help to explain the lack of development of bio-engineering in Hong Kong where a quantifiable factor of safety is paramount in slope stability assessment.

There is an extensive range of bio-engineering techniques in use world-wide. A large number of these techniques are generally low-tech and low-cost with many examples found in developing countries in Asia (Barker, 1999), see Appendix D. In Hong Kong, resources for other styles of slope improvement have been generally available and low cost bio-engineering techniques have been neglected. In addition, bio-engineering techniques are labour intensive and the lack of cheap labour, in contrast to the rest of developing Asia, would discourage their use. As a result there is a lack of labour trained in bio-engineering techniques. Aftercare maintenance is also seen as being labour intensive and therefore costly (Section 7.2.2(5)) and often neglected. On bio-engineered slopes, this lack of maintenance is at best unsightly and at worst will destabilise the slope. Further, while a vocal minority may disparage the use of sprayed concrete, there is a perception among some Hong Kong residents that it is ultimately cleaner and free of vermin, snakes and litter.

It is in this context, largely the result of neglect of maintenance, that bio-engineering, with the exception of hydroseeding, is perceived as having failed to establish itself in Hong Kong.

Slope bio-engineering techniques range from vegetative cover to using plant material to provide semi-permanent structures within a slope. Vegetative cover may include single species, mixed species planting using zonal planting patterns or broadcast planting over a large area, such as the hydroseeding practice used in Hong Kong. Single species planting is generally adopted where a plant has specific beneficial engineering attributes, such as deep and dense root systems that bind the soil; Vetiver grass is a good example of this.

Experimentation with Vetiver has been underway in most provinces in southern China since the 1980s with varying degrees of success (Xia et al, 1999). Recently the use of Vetiver has been endorsed by the Highway Bureau of Fujian Province for use in highway slopes (Xu, 1998). However, there has been a reluctance to use Vetiver in Hong Kong (Hill, 1998), see Table 5.

There is an increasing use of plant material to provide semi-permanent structures, such as brushwood bundles or brush layering across the slope, or 'pegs' of live material that establish rapidly and densely. Examples of this practice can be found in Europe and North America as well as within developing countries in Asia. There are no examples of this technique in Hong Kong. The intended purpose of using live vegetation structures is not to add to the strength of the soil mass, which nevertheless it would do, but to extend the opportunities for using vegetation on slopes where normally there would be a need for more expensive geotextiles.

Considering the initial bio-engineering trials in Hong Kong in the 1980s and its increasing use world-wide, the use of bio-engineering in Hong Kong has failed to establish itself in local practice, with the exception perhaps of hydroseeding. The use of vegetation on slopes in Hong Kong is still perceived as being for aesthetic purposes.

6.3 Green Walls

Of relevance to Hong Kong is the development in recent years in the United States and Europe, but also now in Asia, for example Taiwan and Malaysia, of the use of 'green wall' systems (Table 7, Sheet 10). These are not vertical walls but retained steep slopes where the stability is maintained by tensile structural members embedded in the slope with vegetation established on the wall, through hydroseeding, or direct planting. Two principal systems are used; steel reinforced fill with facing panels or geogrid reinforced fill slopes. Examples of such walls have been used in the USA up to 20 m high, whilst in Taiwan, a recent example was built to 35 m high to provide a construction platform for a housing estate (Tenax Group, 1998).

Whilst green wall systems have been used in Hong Kong before, and there are specifications covering their construction (GCO, 1989), only a few have been constructed. Where there is limited working space, as in many of the existing LPM roadside slopes, there may be insufficient space to carry out the soil compaction operations generally required in green wall systems. The system is therefore possibly better suited to the construction of new slopes. Examples of green walls are in Hong Kong Park, constructed in the early 1990s using Tensar geogrid (Plate 14n) and at Fanling Golf Club, also constructed of Tensar geogrid at about 60° (Plate 12i see Section 7.4.3(8)). Green wall systems, whilst not necessarily appropriate for the higher slopes found in Hong Kong, do offer considerable advantages for the treatment of moderate height slopes in visually conspicuous locations.

7. LANDSCAPE TREATMENTS

7.1 General

The type of landscape treatments adopted for slopes in Hong Kong depends on numerous factors such as location, stability, appearance, cost and maintenance. An evaluation of slope treatments (Tables 5 to 7) provides a description and typical slope application in Hong Kong, where used, as well as an order of capital cost, ease of construction, ease and cost of maintenance and likely longevity of the treatment. The geotechnical and aesthetic advantages and limitations of the slope treatments are outlined together with a recommendation for their use. The summary evaluation is based principally on the findings of observations from a local review of some 200 slopes and information provided by product manufacturers.

The local review involved the inspection of slopes territory-wide by a joint team, comprising a geotechnical engineer and a landscape architect, which evaluated landscape treatments in terms of visual and engineering performance. Details of how the review was carried out are given in Volume 2. The review included a variety of slope types with differing treatments (Table 1). A large number of the slopes visited were suggested by engineering and landscape consultants, GEO, HyD or were slopes cited in relevant publications. The slopes reviewed consisted of mainly roadside slopes, which included 74% cut slopes, 15% fill slopes and 11% retaining walls.

Details of proprietary products used in Hong Kong and overseas, together with contact information for manufacturers and their agents are given in Appendix E. These products are also included in Tables 5 to 7. Much of the information in these tables is supplied by manufacturers and is inevitably biased towards their own product. Prospective users of proprietary products should confirm relevant information with the suppliers with regard to cost and previous or potential use in HK.

A record of trials of some soft landscape treatments in HK is included in Table 13. A useful review of various trials of different vegetated treatments is given in GEO (1999b).

7.2 Soft Treatments

7.2.1 Application

Soft treatments are those that principally comprise a vegetative cover, such as hydroseeding, planting, turfing, and that are intended to give man-made slopes a more natural appearance. A summary of findings of various trials of applying vegetation on slopes is given in GEO (1999b). Examples of soft treatments on slopes included in the local review of slopes are given in Volume 2. Soft treatments should be used wherever possible in mitigation of identified landscape and visual impacts, typically to help the slope blend in with the surrounding landscape. The prescriptive use of vegetation cover on soil cut slopes is given in GEO (1999a).

Soft treatments must be designed with regard to the likely environmental condition of the slope (GCO, 1984) and levels of long term maintenance. The use of vegetation cover for bio-engineering purposes is included in Section 6. The ecology of the proposed vegetation structure should be fully appreciated if it is to be self-sustaining, and not liable to being overgrown or out-competed by other vegetation. Secondary considerations in the use of a vegetative cover include ornamental and amenity values (such as providing shade and shelter) to adjacent street corridors and public areas.

7.2.2 Considerations

In the context of slope planting in Hong Kong, the essentials for healthy plant growth are soil, air, water and nutrients (Table 8). The requirement for healthy growth differs greatly from species to species, and whereas most plants prefer moist well-drained silty sandy soils, in a sheltered and mostly sunny location, their characteristics are most commonly expressed in the form of their tolerances to adverse environmental conditions, such as poor soil, shade, pH and wind. An indication of these tolerances together with an outline description of their physical characteristics can be found, for example in Tree Planting and Maintenance in Hong Kong (SILTG, 1991). It should be noted that the guide is not comprehensive.

(1) Soil. Plants require soil for both the uptake of water, oxygen and nutrients, and for stability. Contact between plant root and soil is required for the healthy growth of all plants.

Soil for planting purposes should be stable, free draining with roughly equal proportions of sand, clay and organic material. This is referred to as topsoil and is generally uncommon in Hong Kong. The most frequently encountered soils are weathered granitic and volcanic residual soils that are suitable for planting, but often require some form of improvement through the application of soil conditioners and fertilizers. In soil cut slopes, this can be achieved through the incorporation of soil conditioner and fertilizers into planting pits or hydroseed mixes. It is not possible to establish effective vegetation cover in sands, gravels or on rock fill. It was noted that vegetation establishment was poorer on soil slopes on areas of decomposed rock grade IV (Plate 12g). This is likely attributable to the relatively greater material strength hindering root penetration. In addition, the likely presence of rock at shallow depth reduces the amount of soil available for trees to anchor roots and can result in shallow tree roots, which may increase the likelihood of tree toppling.

Naturally occurring topsoil is not commercially available in HK, and can only be obtained from excavation of green field sites i.e. newly formed slopes. It is, however, a valuable natural resource for its organic content and natural seed bank. The desirability of stripping and stockpiling it for use in landscape restoration should be borne in mind.

Where no suitable soil material exists, then 'fabricated topsoil' needs to be incorporated into the engineering design of the works. Guidance as to soils for planting works is given in the General Specification for Civil Engineering Works (Hong Kong Government, 1992).

Where soil is placed in planters or on rock fill slopes, the thickness of soil required varies depending on the proposed planting scheme. Generally, grass swards, climbers and groundcover plants require some 300 mm to 600 mm depth, shrubs and tree species some 600 mm to 1200 mm above an inert substrate. Soil for planting should, ideally, not be compacted.

The compaction of soil material as part of the stabilisation works frequently reduces the open and free draining characteristic of the soil. This is especially problematic in silty or clayey soils, such as volcanic soils. Very localised loosening may be necessary around the planting site to allow for adequate root penetration, although loosening for pit planting on fill slopes should be subject to specialist advice.

Most trees, shrubs and grass species can grow on steeply sloping ground provided there is sufficient contact between the soil and the plant roots. The limiting factor is the angle at which a soil slope can be safely constructed. As a general rule for any slope, if the soil can be stabilised without sealing the surface completely then plants will be able to grow on it.

(2) Water. The most common cause of failure of planting works is lack of water. In this regard, the water-bearing capacity of a soil is more relevant than either soil volume or depth. Where planting is into an existing body of soil in contact with groundwater at reasonably shallow depth, then no additional watering is required if planting is carried out between April and July. Where planting is outside the planting season a temporary water supply should be made available for watering up to the start of the next planting season. The availability of water in the slope is a major consideration in the selection of plant species. The need for irrigation on slopes must be considered within the planning and budgeting for any proposed slope works, and where appropriate, specialist advice should be sought.

It is a common misconception that there are drought tolerant species that can be used indiscriminately in landscape works. Water is one of the three essentials for all plant growth, and all nature and naturalised plants in HK require regular water supply from rain, ground water or artificial sources. Succulents and other drought tolerant species from elsewhere in the world, rarely thrive in HK conditions and are of very limited use in mitigating visual and landscape impacts.

Rock berms present special difficulties due to the complete lack of ground water (usually exacerbated by extensive slope drainage systems) and very limited rainfall supply (due to small surface area and a prolonged dry season). If planting is to grow to cover rock surfaces then it needs to have an artificial water supply. If this is not possible it should be understood that the planting will not thrive and have the mitigating effect it is intended to. Irrigation can be an expensive item but is essential to the successful establishment of planting especially on rock berms and should be considered within the planning and budgeting for any proposed slope works.

(3) Surface Runoff. The choice of surface cover, amongst other factors, will determine the amount of surface runoff from the slope. A balance needs to be obtained between low surface runoff rates, which may result in high infiltration and an increase in near-surface pore water pressure, and high surface runoff rates where there is a greater potential for soil erosion problems. Previous work in Hong Kong (GEO, 1995b) has shown that vegetation density is a significant factor in controlling runoff, although the effects of plant species in the GEO study are not clear. A review of the effects of different plant species however can be found in CIRIA (1990). For design purposes, it is prudent to adopt a high runoff rate for surface drainage design, and low runoff rate (i.e. high infiltration rate) for stability analysis.

(4) Plant Selection. Plant types should be selected in relation to the overall objectives of the landscape design. Factors influencing plant selection in Hong Kong relate mainly to the amount of sunlight and water the plants are likely to receive. This is affected by degree of exposure to sun, wind and rain, which in turn is influenced by location, aspect, and presence of other plants and man-made structures. Evidence from the examination of slopes in this survey and from a literature review suggests that almost all HK plants can grow on most angles of slope. The limiting factor is not species but the ability of the slope to support stable

and adequate soil at a given angle and in conditions of extreme weather.

Guidance is given in SILTG (1991) relating to the composition of plant mixes, based on the type of woodland structure to be formed. These are composed of understorey and climax species, with nurse species used to promote growth of plants which are slow to establish in the early years. Recent experience indicates that certain exotic species are so vigorous that without proper long-term maintenance they can easily out-compete all other species. *Acacia spp. Eucalyptus spp.* and *Casuarina spp.* are the most common exotics and should only be used in planting schemes where long term management operations can be guaranteed. These species tend to be very fast growing, and have very dense canopies and aggressive rooting systems, reducing light and moisture levels in the understorey layers. They also have an acid leaf litter which inhibits the growth of other plants.

TDD's work on the restoration of borrow areas and degraded landscape areas, has shown that sustainable native woodland structures can be established through the planting of mixed native and pioneer species, but only where specific long term thinning operations are undertaken to allow sufficient light through the canopy layer (TDD, 1997). They found the use of a single species of pioneer was far less effective, frequently producing monocultural standards of the pioneer. Similar examples can be found in AFD work on the restoration of hillfire damage where single species stand are quite frequent.

The need for long term thinning is emphasised by the planting trials at Shek O where the aggressive pioneer *Acacia confusa* has taken over the entire plot, and effectively killed off (through shading, water competition and acid leaf litter) all other natives and exotic plants. Similar experience on the old landfills e.g. Siu Lang Shui, also suggests that unchecked, exotics will form mono-cultural plantations to the exclusion of native species.

Corlett (1998) notes that *Leucaena leucocephala*, *Syzygium jambos* and *Melia azedarach* have established self-sustaining wild populations. However, the process of natural regeneration of indigenous species can be accelerated with thinning of the pioneer species and other silvicultural operations, to reduce competition.

Ornamental shrubs can add considerable visual interest to a scheme. However they would only be appropriate in areas of high visibility and should not compromise the primary objective of the landscape works. The use of ornamental shrubs should only be considered where long-term maintenance can be assured. Without regular maintenance, ornamental shrubs will rapidly be overtaken by more vigorous invasive grass and climber species.

(5) <u>Vegetation Establishment</u>. Guidance on the establishment of vegetation is given in two equally informative documents (SILTG, 1991) and is covered in practical detail in the 'General Specification for Civil Engineering Works' (Hong Kong Government, 1992). Plant species should be chosen in regard to both their tolerance to known site conditions (microclimate, soil characteristics, …etc) and to their intended landscape and ecological functions.

Planting of all plant types is commonly undertaken by pit planting of individual plant specimens. Grass, some groundcover plants and a limited number of tree species can also be established using hydroseeding or hydro-sprigging techniques.

Special attention should be given to planting through erosion control matting. Cuts made in the fabric to allow plants to be inserted into a pit below, should be kept to a minimum to reduce the possibility of localised surface erosion around the planting pit. Planting through geotextile grids should not be carried out, as these act as tensile reinforcement for the slope.

As a general rule the smaller the size of the plant the more chance it has of surviving the planting process. Conversely, the larger the size the more chance it has of being able to withstand competition from grass and other weeds and the greater its initial visual impact.

Experience from a wide range of restoration projects (TDD, 1997 and others) shows that vegetation on exposed slopes can best be established from seedling and plants (300-600 mm high). Given the variability of live plant material the size definitions given in GS for CE Works should be used with care, and plants no taller than 600 mm high for all species used as a general rule. Of more importance however, is the variable size of plant specimens supplied under these definitions with Contractors frequently offering healthy looking plants that are oversized and thereby unsuited to the conditions.

(6) Maintenance of Soft Treatments. In practice, little or no horticultural maintenance is undertaken on slopes following their completion. Therefore designers, when proposing to use a soft slope treatment should seek the consent of the responsible maintenance agency and ensure that the agency is made aware and committed to long-term maintenance.

Within any new slope formation, the designers are also responsible for the implementation of landscape works. All plants need very specific attention in the period after planting if they are to become sufficiently established to be self-supporting. Planting contracts will generally include a 12-month Establishment Period (EP) in which specific maintenance operations should be performed to ensure the healthy establishment of plants (Table 9). The planting works are then handed over to the relevant maintenance agency. The EP is a vital component of the planting works, and needs to be thoroughly and rigorously undertaken if the objectives of the landscape designs are to be realised. In particular, tree and shrub plants tend to be planted at very small sizes and an effective EP is needed to reduce the chances of the transplants being out-competed by more vigorous weeds. Native plant species are notably slow growing and can be rapidly overrun by the faster growing exotic species (Agricultural and Fisheries Department, 1993).

(7) Long-Term Management Operations. The long term maintenance operations required after the end of the Establishment Period are determined by the type of vegetation cover that is intended. In any event checking of longer term maintenance operations must be carried out by a suitably qualified person.

Grass and Groundcover Plants (Table 10). Grass and groundcover plants are often specified as a landscape treatment as a minimalist vegetation solution, and give an almost immediate green effect. However, both grass and groundcover plants grow rapidly and will need cutting / trimming at least twice a year to remain tidy and to minimise any fire hazard. Grass and groundcover plants will also spread into drainage channels and the regular clearance of these is also required. In addition recurrent maintenance operations should include the clearance of litter, and repair of any damage (fire, typhoon, vandalism etc.). Un-maintained grassland will eventually become colonised by native shrubs and trees.

Where specified as a surface erosion control measure the unchecked growth of grass, and its slow colonisation by larger woody plants are not considered detrimental to the protection of the slope surface.

Woodland Vegetation (Table 11). Woodland vegetation is frequently proposed to screen, to match surrounding vegetation, or to provide greenery to the surrounding area. In combination with grass hydroseeding it is often specified as a surface erosion control measure.

Like the vegetation on the natural hill slopes in Hong Kong once fully established it should grow well without any care or maintenance, and become self re-generating (self supporting). In this respect it should need no recurrent maintenance operations, with the exception of clearance of litter, and repair of any damage (fire, typhoon, vandalism etc.).

To establish a balanced long term woodland structure however requires specific operations to be carried out in the Period up to ten years after the Establishment Period. Until the trees and shrubs grow to form a continuous cover, grass and groundcover plants should be maintained as described in the paragraphs above.

Woodland planting mixes typically include fast growing exotic species (e.g. *Acacia*, *Eucalyptus* and *Lopostemon spp.*) to promote micro-climates that will help the establishment of slower growing natives. These exotics have to be progressively removed in the period 5 to 10 years after establishment by a process known as thinning. This involves the selective removal of exotic trees to create more light and space between the trees. Experience on a wide range of projects (TDD, 1997 and others) shows that if this is not undertaken then the exotics will colonise the whole area, effectively out competing the native species and forming a dense plantation with no ground level 'understorey' plants. This is not sustainable as it does not suit the surrounding ecology and potentially exposes the slope surface to erosion as there is no understorey plants and to sudden denudation when the trees die. Also any wind damage (in typhoons) tends to be far more extensive in close set, single species stands of trees, than in structured native woodlands.

7.2.3 Evaluation of Soft Treatment Types

A summary evaluation of soft slope treatments (Table 5) shows that the more common treatments, such as hydroseeding, are generally applied to soil slopes up to about 45°. Some proprietary products, as specified by the manufacturer, can be used on steeper slopes up to about 70° to 85° and on landslide scars, see Table 12 for examples.

Capital cost of soft treatments are less than HK$500 per m^2 with the cheapest being hydroseeding at less than HK$50 per m^2 based on current market estimates. The use of a vegetative cover with a geotextile (Appendix E) would increase the cost, depending on product, by between HK$5 per m^2 and HK$75 per m^2. By comparison, sprayed concrete is of the order of HK$350 per m^2.

For most soft treatments, construction is relatively straightforward with few specialist skills or machinery required and with materials commercially available locally. Maintenance costs are generally low, with no specialist maintenance required. If the vegetation is well established then it will last a lifetime, though geotextiles, again depending on product, can last from anywhere between 2 years for organic to 200 years for synthetic polymer geotextiles.

The following is an evaluation of the main soft landscape treatments encountered in the inspection of local slopes. Altogether 29 slopes with 5 soft treatment types were inspected (Table 1).

(1) Hydroseeding with Grass Seeds. A sprayed mix of grass seed, macerated paper and fertilizers in a water suspension applied to soil slopes. The use of this technique has become very common on man-made soil slopes in Hong Kong. Altogether 17 slopes were visited where grass hydroseeding was used in combination with trees and shrubs, or with erosion control mats (see below). Grass hydroseeding was used as the dominant treatment in 6 of the slopes visited. The inclination of these slopes ranged from about 35° to 45°.

The greening effect of grass is considered visually pleasing (Plate 12a) and most slopes visited were given a relatively successful aesthetic rating. The inclusion of other plant species by pit planting generally improved the overall appearance and added to bio-diversity. A recently upgraded 40° soil cut slope at Sai Sha Road which is dominantly hydroseeded with grass but includes some mixed species tree whips (Plate 12b) is an example of this.

Grass hydroseeding was found to have established successfully on all slopes visited up to the observed maximum inclination of about 45°. However, grass can be successfully grown on much steeper slopes. Inspection of soil slopes with (possibly?) self-seeded grass showed that grasses successfully established on soil slopes up to about 75° (Plate 12c). Inspection of steep (55° to 75°) vegetated soil cut slopes, typically about 5 m high and unsupported, at Kadoorie Farm, New Territories found numerous small failures. Some localised erosion gullies were also present.

Where a soil slope can be safely supported, there is no limit to the slope angle at which grass (or other vegetation) can be established. However, at steep slope angles, taken as greater than 45°, other factors, such as surface erosion, make hydroseeding with grass increasingly impractical.

To maintain grass as a finished surface treatment it should be cut at least twice per year, more if it is intended for ornamental purposes. If it is not cut, the grass will be taken over by more robust, slower growing woody species, or climbers. Where grass is in proximity to drainage channels, it may eventually invade the channels causing blockage (Plate 12d) unless routine slope maintenance is carried out.

(2) Hydroseeding with Grass and Tree/Shrub Seeds. A sprayed mix of grass, tree and shrub seeds, macerated paper and fertilizers in a water suspension. This planting technique is becoming increasingly popular because it is a cost-effective method of sowing a variety of plant species in one operation. The use of native tree seeds in tree seeding mixes should be further investigated. Kadoorie Farm are currently experimenting with native species, and Highways Landscape Unit are undertaking trials on the establishment of native species, especially grass and tree species by hydroseeding. However the result from these will not become known until late in Year 2000.

The review included 23 slopes where this technique was the dominant treatment or used in combination with other treatments. The range of slope inclinations were between about 25° and 60°. On most of the slopes visited, the vegetation was well established, the technique having been applied between about 10 years and 15 years ago. This group of slopes was rated as one of the more aesthetically successful at integrating into its surroundings, for example at Ching Cheung Road near Butterfly Valley (Plate 12e).

In general, most slopes visited showed very few signs of distress. The exception to this was a section of 60° nailed soil cut slope with erosion control matting on Sheung Fung Street (Appendix B). The trees on the slope were notably leaning with signs of uprooting accompanied by surface erosion and general shallow instability.

Closer inspection of this group of slopes found a dense clustering of trees, generally at about 1 m to 2 m spacing, with little or no groundcover plants underneath (Plate 12f). The close spacing of trees has resulted in relatively tall slender trees, which may be prone to toppling as they grow and mature. The trees are also thought to be much more short-lived and problems of sudden future die-out of whole tree plantations, leaving the slope exposed, have been suggested. In addition, the dense tree canopy inhibits sunlight reaching the slope surface and for this reason has likely contributed to the absence of groundcover plants. The absence of groundcover does however result in drainage channels that are relatively clear of vegetative matter. Given the absence of groundcover, soil erosion beneath the canopy did not appear to be notably greater than that seen on other slopes with groundcover.

From an ecological point of view this technique is not favoured as the range of tree species with sufficiently small sized seeds that can germinate and establish rapidly enough not to be over-grown with weeds is limited to a few very aggressive exotic trees. These tend to produce mono-cultural tree plantations of little or no inherent ecological value.

This technique provides a successful means of integrating a soil slope into its surroundings. Based on the above findings, limiting the technique to slopes less than 60° appears to be a reasonable practical upper limit.

Research into native tree species which might be used in this way is required. Also, the adoption of a strategy for long-term management operations to overcome the problem of overcrowding of trees with this technique merits further study, see also GEO (1999b).

TDD's experience (TDD, 1997) suggests, however, that native ferns, followed by woody plants and native trees ultimately invade exotic plantations, more rapidly so, where thinning operations have been carried out.

(3) Grass Hydroseeding with Pit Planting of Seedling Sized Trees and Shrubs. An approach in which slopes are grass hydroseeded and then pit planted with tree and shrub species at seedling sized trees (typically 300 mm to 600 mm high). This technique provides an improvement over hydroseeding with tree/shrub seeds in that it avoids overcrowding of trees, allows greater control of placement of plants and the use of a very much wider range of tree and shrub species.

The review included 27 slopes in differing settings and different ages from recently planted to about 10 years old. This group of slopes was rated as one of the most aesthetically successful at integrating into its surroundings. Most slopes visited were soil cut slopes with inclinations of between about 25° and 45°. At steeper inclinations, it becomes harder to gain ready access for planting, and in practice, the incidence of localised surface erosion around planting sites is likely to increase.

From the results of the review, the visually pleasing element of the landscape treatment was the natural variation in texture and colour provided by the planting pattern of the vegetation established. The plant selection and planting pattern need to be undertaken by landscape professionals. This however provides for a planting scheme that optimises the visual quality of the slope, reduces horticultural maintenance requirements and ensures the placement of plants to minimise the interference with the engineering performance of the slope.

This technique provides the best available method of greening soil slopes up to about 45°. The benefits of this technique, in terms of overall visual quality and long-term maintenance, are considered to outweigh its relatively higher cost compared to other hydroseeding methods.

(4) Ornamental Tree, Climber and Groundcover Planting. This is the ornamental planting of tree, shrub and groundcover plants in planter beds. The review only encountered 3 slopes that contained planter beds. The limited number of planter beds on slopes is because of the continuous maintenance required to ensure the ornamental quality of the bed.

In most situations, planter beds are not considered for use in general slopeworks. Those encountered during the review were located on slopes in areas of high visual importance, such as areas with a high concentration of people, visually sensitive settings such as central urban areas, or areas where there was a high level of horticultural maintenance as at Kadoorie Farm (Plate 12h).

The need for continuous maintenance requires readily accessible sites with water irrigation facilities. The design of ornamental planter beds requires the use of landscape professionals.

(5) Self-seeded Groundcover. Strictly speaking, this is not a planned slope treatment but the review noted that on 23 of the slopes visited the dominant vegetative cover was self-seeded groundcover plants, i.e. plants germinated from seeds transported to the site by natural processes, such as wind. Groundcover plants included grasses, ferns and creepers. These self-seeded plants either established themselves on slopes where no planting was carried out, such as possibly on the steep slopes at Kadoorie Farm (Plate 12c), or out-competed planned vegetation, for example on the geogrid reinforced slopes at Fanling Golf Club (Plate 12i). The self-seeded plants were found to be growing successfully on relatively steep inclinations up to about 75°.

Given that these groundcover plants have shown themselves to be adaptable to a range of slope conditions and occur naturally locally, there is the potential to utilise these groundcover plants as part of a planned slope vegetation cover. Further work to identify suitable species for commercial use is required and trialling would need to be undertaken.

7.3 Hard Treatments

The architectural treatment of hard engineering features, in particular the treatment of retaining walls, buttresses, and sprayed concrete surfaces can do much to reduce their visual impact in the landscape and improve the overall visual quality of the scheme. If anticipated in the planning stages these can be achieved with relatively little additional expense or implication on design or construction programmes. Examples of hard treatments on slopes included in the local review of slopes are given in Volume 2.

7.3.1 Application

The aim of any architectural treatment should be to reduce the visual contrast with the surroundings. Large-scale monotonous features tend to be visually incongruous in their surroundings.

Changes in vertical and horizontal profile, patterning, and cladding, and the incorporation of colour can all help to create a more human scale and proportion, and a visually more pleasing appearance.

Finishes and materials should be chosen to complement the surrounding structures and building forms e.g. granite facing has successfully been used for a skin wall on Eastern Street, Mid-Levels Road to complement the existing masonry wall (Plate 14x). At Kowloon Park Drive, a combination of masonry cladding and artificial glass fibre reinforced concrete rock work created a unique wall appearance (see Volume 2, Appendix C, Study No. 47). Architectural treatments should also be carried out in a coherent manner for the whole site, rather than for one or two items.

The use of any architectural finishes should be evaluated in respect to their additional capital and long term maintenance costs.

7.3.2 Considerations

(1) Staining of Hard Surfaces. Staining of hard surfaces can occur in a relatively short period from washing down of rainwater or discharge from weepholes which can seriously diminish the visual appearance. Good drainage detailing can usually minimise the negative effects of staining, see for example Chapter 17 Aesthetics in HyD (1993).

For retaining walls, the design of the coping feature is essential to minimising water running onto the wall face in heavy rain. The coping and level ground above a retaining wall on Gascoigne Road is a good example (see Volume 2, Appendix D, Study No. 46). A bad example is a heavily stained retaining wall on King's Road, below Kornhill at Tai Koo where a steep slope above the wall concentrates water flow onto the wall face (see Volume 2, Appendix C, Study No. 45).

On sprayed concrete slopes the efflorescence precipitated from water, seeping from weep holes in the face leaves unsightly stains on the surface of the wall. The bright white colour of the efflorescence is most apparent when colour pigments have been used in the sprayed concrete. An effective means of controlling the efflorescence and the visual impact is the location of weep holes in recesses or grooves in the face, more commonly found in retaining walls, for example below Chinese Christian Cemetery, Victoria Road (Plate 13p). The number of weep holes also commonly appears to be excessive with no signs of seepage from most of the holes. It was observed that some notable schemes such as Kowloon Park Drive did not appear to have any (see Volume 2, Appendix C, Study No. 47). An alternative approach is to use a variegated paint finish to hide possible staining.

In discussions with suppliers of colour pigment for sprayed concrete (pers. comm. Mr Colin Bosher - Sterling Chemicals Ltd) products were available on the market to seal the surface of coloured concrete to prevent efflorescence from occurring. These were expensive given the large quantities required and length of time to apply.

(2) Colouration of Sprayed Concrete. Colours should be chosen to match or complement the surrounding environment. From discussions with suppliers, it is noted that the colour charts are only guides and true colours are subject to the proportions of the mix, and the specific nature of the concrete materials. The specific colour should be examined in detail and colour samples tested on site for visual verification.

Difficulties in mixing colour pigment into concrete to achieve colour consistency, especially in patchwork repairs, were noted by several contractors and by Highways Maintenance Department. In patchwork repairs, it is virtually impossible to achieve colour consistency given that the shotcrete in place will have been discoloured by weathering. Guidance on both the introduction of colour into shotcrete by admixing in the wet and by surface painting has been included in recent contracts for the Highways Department.

(3) Drainage and Slope Infrastructure. Most slopes will require drainage and maintenance access via stairways etc. Visually, these are often the most striking aspects of a slope. Measures can be taken to reduce the visual impacts of these features and they can be built into the overall aesthetic design of the slope. Section 5.3.2 and GEO (1993) refer. These include recessing built drainage features such as channels, step channels, catchpits etc. back into the slope so that their visual depth is reduced, and by colouring concrete works with pigments to match the surrounding landscape, as at Shek O Quarry (Plate 11a).

(4) Style. Artistic and graphic designs should always be used with care, and preference given to abstract rather than pictorial images which quickly tend to become out-dated.

(5) Maintenance. The durability of any artwork should be thoroughly investigated. Colour fastness should be checked with the manufactures specifications as colours in many materials will fade under the intense UV light. In discussions with suppliers of paint for concrete (pers. comm. Mr Colin Bosher - Sterling Chemicals Ltd) it was noted that there is a range of finishing products available to reduce colour fading on concrete. In addition, effects achieved with subtle colour or patterning tend to become obscured by staining and the high level of particulate pollution in Hong Kong.

Some paints and applied finishes to concrete surfaces commonly have high maintenance commitments. Although cladding panels and applied finishes can limit the opportunity for visual inspection of structural elements this should not be seen as a restriction on their use.

7.3.3 Evaluation of Hard Treatment Types

An evaluation of hard treatments is given in Table 6. Hard treatments include a wide range of slope types, such as soil slopes with hard slope surfaces, e.g. sprayed concrete or masonry cladding, or rock slopes. Retaining walls are also included in this treatment type.

The following is an evaluation of the main hard landscape treatments encountered in the inspection of local slopes. Altogether 51 slopes with 12 hard treatment types were inspected (Table 1).

(1) Sprayed Concrete (untreated). Concrete mix sprayed on to the surface of the slope to form a layer typically about 75 mm thick which may contain a light mesh reinforcement. This technique has been increasingly used over the last few years on almost all slope types. Current practice however is to limit its use, due to its adverse visual appearance. This was the most commonly encountered slope treatment in the review with 75 slopes either completely covered or partly covered with sprayed concrete. The treatment was mainly found on cut slopes and a few fill slopes. The distribution of slope angles ranged from about 25° to 80° (Figure 4) with about 60% of sprayed concrete slopes with slope angles greater than 55°. A comparison with all soil and soil/rock slopes of 45° and over shows that 60% have a sprayed concrete (untreated and without colour pigment) cover.

Untreated sprayed concrete slopes are recognised as being visually unsatisfactory. The review cited the following reasons for the poor visual quality: monotonous surface, little visual interest, unnatural, high albido (reflectance) and in stark contrast with its surroundings. For example, even relatively small slopes remain highly visible against their surroundings (Plate 13a). Where part of the surface could be screened using vegetation in planters or tree rings this mitigated some of the visual impact. In addition, long-term weathering of the sprayed concrete darkened the surface marginally reducing albido and visual impact.

(2) Sprayed Concrete with Colour Pigment. As for sprayed concrete but with the addition of colour pigment either at the time of spraying or added later. The review included 21 slopes with this treatment with slope angles that ranged from 35° to 85°. Examples of this treatment include slopes along Tai Tam Road and Wong Nai Chung Gap Road (Plate 13b).

Coloured sprayed concrete slopes were considered as moderately successful in integrating into their surroundings. Generally, one colour was used, typically a shade of brown. Occasionally, several colours were used in an attempt to provide a more naturalistic colouring and patterning, such as on the North Lantau Expressway (Plate 13c). Colouring was considered especially effective at blending the slope into its surroundings when viewed from long-range. In closer views, where a single colour was used the result was considered less effective, the uniform colouring tending to look unnatural.

The review noted that different colours were used on slopes within short distances of each other along a roadside. This, it was felt, was visually confusing and tended to draw attention to the slopes. The adoption of a roadside colour scheme based on the local environmental setting would be beneficial.

It should be remembered that simply colouring sprayed shotcrete, while reducing the glare and starkness of the usual light grey and white, is no more than token landscape treatment if it is visually poor. Generally, lighter colours contrast sharply with adjacent natural vegetation and should be avoided. Darker colours are more recessive and simulate shade. Plates 13e and 13f are contrasting examples from Tai Tam Road. Plate 13e shows the glare from light grey shotcrete and the contrast with natural vegetation. In Plate 13f, the dark colouration of the chunam lessens the glare and contrast with the vegetation. At Po Lam Road, darker coloured shotcrete and the retention of trees have softened the visual impact.

Large areas in a single colour, such as the upper sections of Wong Nai Chung Gap Road (Plate 13b) tend to look unnatural. Colour combination can give visual interest. The retention of natural profiles under the pale brown shotcrete as on Tai Tam Road at Pacifia View (Plate 13h) creates a pattern of shadow which reduces the monotone effect of a single colour.

(3) <u>Chunam</u>. A soil and cement mix applied generally by hand trowel to a slope surface to create a rigid impermeable cover. This treatment was more popular in the past, sprayed concrete is more often used at present to provide an impermeable cover. The review included 3 chunam surfaced slopes with slope angles ranging from 50° to 80°. The visual quality of this treatment is generally considered unsatisfactory for similar reasons as given for sprayed concrete.

(4) <u>Slope Surface Cladding</u>. Generally granite masonry set in mortar. This treatment is used to provide a complete surface cover or as a part covering to a slope where particularly softer material is present. The review included 21 examples of slopes with surface cladding with slope angles ranging from about 25° to 35° for fill slopes and from about 35° to 75° for cut slopes. Several good examples were visited, most notably at the southern approach to Lion Rock Tunnel (Plate 13d) and, as an infill on a rock slope, opposite Heng Fa Chuen Estate (Plate 13i). At Lion Rock Tunnel Road, the use of masonry with varying topography was considered to provide a visually interesting feature. The slope opposite Heng Fa Cheun Estate is a rock cut slope with a closely-jointed rock mass which is matched by the texture of the masonry infill resulting in the masonry visually blending into the slope.

Where surface cladding is prescribed, the use of larger units at the bottom and progressively smaller ones higher up can help to visually reduce the scale of the feature making it less visually intrusive than slopes with uniform- sized surface units e.g. Deep Water Bay Road (Plate 13j).

(5) <u>Soil Nailing with Hard Cover</u>. This includes soil nails with generally a sprayed concrete cover. The review included 10 slopes with slope angles ranging from about 40° to 60°. This treatment took two forms, either a raised nail head or a countersunk nail head integral with the hard cover. The raised nail head appears to have been an older detail which is visually highly intrusive, an example is shown for a slope on Sai Sha Road (Plate 13k). The countersunk nail head is similarly visually intrusive as shown for a slope on Ap Lei Chau Bridge Road (Plate 13l). The visual quality of this treatment is considered unsatisfactory for the same reasons as given for sprayed concrete.

(6) <u>Gabion</u>. A proprietary product formed of a rhombic wire mesh box, commonly with 1 m^2 faces, which is filled with broken rock. Gabions are generally used stacked

together to form a gravity wall/or facing structure. The product has been available in Hong Kong for about 10 years but has generally been used on small-scale works. The review only visited two gabion slopes, and these were of a minor nature.

The product can provide an interesting visual appearance, where for example the infill rock is layered to re-create a random masonry pattern (Plate 13m). There is also the potential to include planting pockets in the boxes.

(7) Crib Wall. Gravity retaining wall system constructed of pre-cast concrete units with stone infill. Crib walls have been used in places in Hong Kong; an example from Fung Shue Wo Road, Tsing Yi is shown in Plate 13n.

The aesthetic review found the regular rectangular grid of the wall provides a visually interesting texture and the pattern reduced the scale of the wall. The wall was considered moderately successful in integrating itself into its surrounding. To reduce the visual impact of the wall, crest and toe planting should be considered.

(8) Wall Facing and Finishes. The review included 41 retaining walls with a variety of facings and finishes. The more visually successful examples visited included those that had a mixture of co-ordinated hard textures, such as at Victoria Road (Plate 13o), or successfully used vegetation to reduce the impact of the wall, Victoria Road (Plate 13p). Several examples of walls with graphic facing panels were also visited, one of the more successful of these was at Gascoigne Road (Plate 13q). Here the graphic design was successfully combined with planting at the toe to create a visually interesting feature.

Standard wall facing and finishes, as for example in CED (1994), provide an acceptable level of visual quality, which may be enhanced by the additional use of plants. The use of graphical designs has the greater potential for failure as designs become outdated and public tastes change.

(9) Rock Protection Wire Mesh. Typically a galvanized and PVC coated twisted wire mesh draped over a rock face to protect against small-scale rockfall. The review included 5 slopes with rock slope angles that ranged from 45° to 70°. Mesh is not considered as a landscaping treatment in Hong Kong, though in other countries it has also been used as a means of supporting vegetation on rock slopes. Mesh is particularly useful in landscape terms as it is not visually apparent in medium and long-range views allowing the natural colour and texture of the rock to be shown. Wire mesh can be visually obtrusive at close-range particularly where the anchoring systems are obvious.

(10) Rock Buttresses. Generally, a concrete block cast in situ on to a rock face to provide additional support to the face. The review visited 30 rock slopes with buttresses with slope angles ranging from 35° to 85°. Buttresses are not commonly given any landscape consideration yet a buttress may be the most visually dominant feature on the slope. The review found that buttresses were generally visually intrusive due to their size, unnatural shape and colour against the small-scale texture of the rock (Plate 13r). Some principles to be considered in the landscape treatment of buttresses are shown in Figure 5. Buttresses should generally receive some form of architectural treatment to minimise their visual impact through careful consideration of their shape, colour and/or facing and proportion within the slope and to each other. Where a series of buttresses is used, designers should endeavour to

ensure that they are of a similar shape and proportion, matching, where possible, top lines, sectional profiles and overall dimensions into a visually unified family of structural elements. In Plate 13s, buttresses have been spaced to allow existing trees to be retained and have been faced with granite. The overall visual effect is relatively successful. In Plate 13t, the buttress has been coloured to suit the overall landscape. There has also been an attempt to provide the appearance of a random natural rock finish. While the landscape effort is apparent in the finish, the overall effect is disappointing.

(11) Rock Exposure. Nearly 25% of the slopes included in the review were either rock cut slopes or contained an element of rock cutting. Slope angles ranged from about 30° up to 90°, with an average of about 54°. This is not normally considered as a landscape treatment but it is considered that rock exposures provide an attractive colour and texture which complements the surrounding landscape resulting in a reasonably pleasing visual appearance. However the potential attraction of the natural look of the rock was affected by the use of blasting techniques which introduced artificial patterns into the rock through remnant vertical blast holes and smooth regular faces (Plate 14t).

Where possible, alternative blasting techniques should be used that produce a cut face sympathetic with the natural jointing of the rock mass. For example, the rock faces produced at the Turret Hill Quarry (Plate 14s), see Appendix B.

(12) Rock Bolts. A method of stabilising potentially unstable rock using threaded metal bolts embedded in the rock with an anchor plate cast in a concrete cover on the rock face. Construction details typically follow CED (1994). A common engineering device that generally receives little landscape consideration. This is not regarded as a landscape treatment but bolts can be arranged to limit the visual impact. The review included 8 rock slopes where bolting had been used. On most of the slopes, occasional spot rock bolting was generally used which has little visual impact. Where pattern bolting was used the visual impact is greater, though it was considered that on large even rock faces a regular bolt spacing within a geometric pattern usually gave an acceptable visual appearance (Plate 13u).

7.4 Mixed Treatments

7.4.1 Application

For many slopes the solution is a mix of both hard and soft treatments, and the work of the designers will be in achieving the balance between the two which optimises the visual impact. Examples of mixed treatments on slopes included in the local review of slopes are given in Volume 2. Evaluation of mixed slope treatments is represented in Table 7.

Typical solutions include planter walls either at the toe or along berms, surface planting pockets and the use of hard features such as grillages, grasscrete, gabions and crib walling which allow planting to be incorporated into an otherwise hard treatment.

In considering the choice of treatment, designers should bear in mind the location of the visually sensitive receivers and should endeavour to arrange the composition of the slope so that they receive maximum benefit from the soft treatments. For example, if the slope is seen mainly from a road or footpath below, then toe planters should be favoured. If most people view the slope from elevated viewpoints then berm planters or surface planting pockets might be favoured.

7.4.2 Considerations

In mixed treatments, the conditions for establishing planting are likely to be more restricted than in soil slopes, especially in respect to reduced soil volumes, limited water supply, and higher degree of exposure due to surrounding hard surfaces. Typical treatments include:

(1) Toe and Berm Planters. A toe planter at the foot of a slope will generally be appropriate and in certain cases will have the effect of mitigating impacts at street level. Berm planters in some cases may be the only means of introducing vegetation onto a slope face and therefore can have a striking visual impact if executed properly.

(2) Surface Planting Pits. Planting pits are used on the slope surface where a hard surface covering such as sprayed concrete or chunam has been applied. The pits provide a simple means of introducing vegetation into the slope and help to break up the uniform appearance of the slope.

(3) Grillages, Grasscrete, Gabions and Crib Walls. These are all hard engineering elements designed to allow the incorporation of planting into a slope surface. Although they vary considerably in size and scale, as a general rule they tend only to be effective where the volume of planting that can be established will be sufficient to soften the appearance of the slope and the structure itself.

Key considerations in the use of such structures are the volume of soil that they can hold, and the source of water. Where soil in the planting pockets is in contact with natural soil bodies then the planting is usually able to establish and thrive. Where small pockets of planting are surrounded by free draining inert material within the structure then the planting rarely succeeds.

Even without planting, such structures are frequently more attractive than plain retaining walls or sprayed concrete finishes due to their smaller scale unitary composition, that visually has some scale and depth.

7.4.3 Evaluation of Mixed Treatment Types

An evaluation of mixed slope treatments is given in Table 7. Mixed slope treatments include any treatment that has both hard and soft elements. This includes a wide range of slope types and most of the slopes inspected.

The following is an evaluation of the main mixed landscape treatments encountered in the inspection of local slopes. Altogether 115 slopes with 20 mixed treatment types were inspected (Table 1).

(1) Synthetic Erosion Control Mats with Hydroseeding/Planting. Synthetic mats are generally used on vegetated slopes that are prone to long-term soil erosion problems. The

most common type of mat used is a 3-dimensional random polyamide matting with an open structure that traps soil particles and allows root development. The review visited 18 slopes where mats had been used with a variety of tree, shrub and grass covers. Slope angles typically ranged from 40° to 60° for cut slopes and about 20° to 45° for fill slopes.

On most of the slopes the erosion control mats were laid directly onto the slope surface, and sprayed with a hydroseed mix. This gave a reasonable result in terms of visual appearance and engineering performance. Minor problems identified included failure of vegetation to establish fully and lack of contact between the mat and the soil surface, particularly on undulating slope surfaces. Where the mat is not in intimate contact with the soil surface it is unlikely that vegetation will establish and it is likely that erosion will take place beneath the mat (Plate 14a). An alternative installation procedure is to fill the mat with soil after laying and before seeding. There were fewer examples of this; a recently completed slope on Bowen Road illustrated the problem of overfilling the mat with soil which resulted in erosion of the soil above the mat (Plate 14b).

With regards to the establishment of larger plant species there are two key areas of concern. Firstly there is the difficulty of cutting the matting to allow subsequent pit planting of trees and shrubs, without affecting the integrity of the mat or promoting localised surface erosion. Secondly, the mats may cause some restriction on plant growth where stems thicken to the extent that the mat can no longer expand to accommodate them, resulting in strangulation at the base of the stem. This can limit mature plant growth and induce structural weakness in the plants (Plate 14c).

These are several potential means of limiting the difficulty of planting and establishing larger plants through erosion control mats but none of them have been identified as being commonly used in Hong Kong:

(a) the use of other measures such as rockfill to reduce localised surface erosion near the stem of a tree where erosion control mats are absent,

(b) the use of biodegradable erosion control mat near the stem of a tree to avoid strangulation of the tree, and

(c) the rearrangement of mat layout to avoid cutting of mats.

Trials with synthetic erosion control mats in Hong Kong have shown the mats to be relatively successful in controlling soil erosion (GEO, 1999b). Minor, essentially installation-related problems of localised wash-out and difficulty of plant establishment still occur. It is important therefore, that the manufacturer's specification for installation is rigorously followed. The manufacturer's advice or supervision should be sought in cases of doubt.

(2) Biodegradable Erosion Control Mats with Hydroseeding/Planting. These mats are used on slopes to control short-term soil erosion until vegetation can be established. They are made of woven organic fibres, such as coir (coconut fibre) and jute, to form a mesh (of varying density and weight) that is laid over a seeded soil slope. The intention is that the plants grow to establish an effective cover to the slope, within the time it takes the mats to biodegrade (some 2 years to 10 years). The advantage of biodegradation is that there is no

permanent artificial element in the slope which can compromise the natural ecology of the site.

There are few examples of slopes where biodegradable mats have been used. The review visited 2 slopes, a 25° fill slope and a 45° soil cut slope. However, GEO (1999b) reports a trial in 1990 of a biodegradable jute mesh (Soil Saver) carried out in Siu Lam which demonstrated that vegetation could be successfully established on a 50° soil slope.

The review included a visit to Shek O Quarry where the slope rehabilitation work is using Soil Saver matting with hydroseeding and planting over a compacted soil laid over blast fragmented rock scree slopes (Plate 14d). Finished slope angles are typically 25° to 35°. The slopes at Shek O Quarry are still under construction and it is too early to draw any conclusions on the performance of the biodegradable matting.

Biodegradable matting has been used on a 45° soil cut slope completed in 1996/97, at Lion Rock Service Reservoir (Appendix B Case Study No. 11). Minor erosion has occurred on the slope, washing soil from beneath the biodegradable mesh and exposing a synthetic mat beneath (Plate 14e).

Biodegradable mats offer a cheap and more environmentally friendly alternative to synthetic mats. However, due to the decomposition of this product within a few years (about 2 years at Siu Lam) it can not be used as a substitute for synthetic matting where there are potential long-term soil erosion problems, such as steep slopes with erodible soils. They may have specific use near the stem of a tree to avoid strangulation of the tree, although the use of pebbles to reduce localised surface erosion near the stem of a tree in the absence of erosion control mats can also be considered.

In general, there are too few examples of biodegradable mats to draw any firm conclusions and further study into biodegradable matting should be considered to establish under what conditions it can be used as a suitable alternative to synthetic matting.

(3) <u>Soil Nailing with a Vegetation Cover</u>. Soil nailing has become an increasingly popular method of stabilising steep soil cut slopes. A soil nail comprises a galvanized mild steel bar with a grouted annulus placed in a pre-drilled hole within the slope. At the slope surface, the nail is secured in position by an anchor plate and locking nut which are cast in concrete to form a square-shaped nail head. The review included 7 soil nailed slopes with grass and tree cover, with slope angles that ranged from about 40° to 60°. This technique was considered aesthetically successful, as the only apparent sign of nailing is the nail head.

On several of the slopes visited, it was not readily apparent that soil nailing had taken place as the nail heads were effectively screened by the vegetation cover. For example, at Ap Lei Chau Bridge Road, (Appendix B Case Study No. 5) following repeated landslides along an extensive roadside cut slope, stabilisation works were carried out using soil nails. The slope angle was about 40° and the slope was mostly covered in mature trees. The soil nails, arranged on a 2 m x 2 m grid were constructed to minimise disturbance to the existing trees. The soil nail heads used were a standard detail (CED, 1994), about 0.35 m x 0.35 m in size and countersunk into the slope face (Appendix B).

Above Cheung Ching Road, Tsing Yi, a 40° soil and rock cut slope, the upper soil slope is stabilised in part with soil nails. The soil nail heads are now completely hidden by trees, mainly *Causarina equisetifolia* (Plate 14f).

Where soil nails are used with a grass cover, the nail head may still be visible. This however does not detract notably from the visual appearance, especially if the nail heads are kept as small as possible. At a recently completed 45° slope on Tai Chung Road, Shatin (Plate 14g), grass had failed to establish over the nail heads.

At Sheung Fung Street, a section of 60° soil nailed slope with hydroseeded grasses and trees shows signs of shallow soil instability with leaning and partially uprooted trees (Plate 12f).

Soil nail stabilisation is generally visually unobtrusive and provides a significant surface area on which to establish a vegetation cover. In most cases, the nail head is effectively hidden by the vegetation. On grass slopes, where the nail head is relatively large, it is important to ensure that the head is countersunk, soil is placed around the head and underneath the erosion mat, if used, and that hydroseed is generously applied over the head. It is also considered that the placement of nails in a regularly spaced geometric pattern gives a better visual effect than a random distribution.

(4) Grillages. Usually a regular arrangement of connected reinforced concrete ground beams constructed on the slope surface. The beams are usually anchored into the slope, in which case the beams are used to transfer the compressive anchorage force across the slope surface. There are few examples of grillages in Hong Kong. The review included 3 slopes: at Victoria Road, Lion Rock Tunnel Road and Tsing Yi Road. These slopes were predominantly soil or rock/soil cut slopes with gradients that ranged from about 35° to 65°.

For the slopes visited, grillages were used for structural stability and it appears that little attempt was made to use the grillage for a landscape purpose. At the mixed soil and rock cut slope at Victoria Road (Plate 14h), the grillage consists of a regular grid of beams about 0.3 m wide by 0.3 m deep at about 1.5 m centres, which provides potential planting cells between beams.

Grillages offer an opportunity to adapt a hard engineering solution to support vegetation on steep soil slopes. It is considered that a grillage can be readily integrated with soil nails, a common slope stabilisation technique, to provide a practical design solution for steep slopes. However, the pattern formed by the grillage beams, for example a regular geometric shape or an asymmetrical pattern needs to be designed to suit both local site conditions and the visual and landscape requirements. It would be anticipated that, with appropriate design, a grillage would be capable of supporting vegetation on any soil slope that could be stabilised using soil nails. A practical upper limit for the use of grillages on soil nailed slopes is about 70°.

(5) Grasscrete. A proprietary technique that comprises a reinforced concrete cast in situ (or sprayed concrete) layer with closely spaced soil-filled voids used for planting grass. The technique was primarily developed for use as a lining in water channels subjected to periodic water flow and inundation, it is therefore capable of withstanding more severe conditions than normally found on a slope. Given the primary role of the technique it is not commonly used on slopes. Only two examples were visited, at Tin Wan Hill Road and the man-made slopes along the Lam Tsuen River channel.

Grasscrete (possibly an early or modified version) was used on the upper portion of a 35° soil cut slope constructed in 1987 at Tin Wan Hill Road, Aberdeen (Plate 14i). Inspection of the slope found a reasonably successful vegetation cover, which when viewed from long-range appears as a continuous green covering, even though the planter voids account for only about 10% of the surface area. When viewed close-up the Grasscrete is visually unattractive. Planter voids at this site are circular with a diameter of about 150 mm, spaced at 400 mm centres.

Within the Lam Tsuen River, Tai Po, the 35° Grasscrete channel slopes are formed using a planter void arrangement that accounts for about 50% of the surface area. This provides a visually pleasing expanse of vegetation (Plate 14j).

This technique is considered successful in producing a greening effect whilst still maintaining a significant area of hard surface covering. The technique demonstrates that a reasonable level of greening can be achieved with the use of only a small amount of planting area.

The recommended maximum slope angle for this technique is 45°. Communications with the manufacturer (pers. comm.) have indicated that with some modifications the technique can be constructed with sprayed concrete on slopes greater than 45°. Modifications are minor and include increasing the rigidity of the plastic planter void formers, use of 450 mm long steel staples to secure the Grasscrete to the slope and a soil/gravel mix fill in the planter voids.

(6) <u>"Creat" Strip and General Toyo-Mulching</u>. Proprietary products comprising a sprayed mix of grass seeds, binding agent, fertilizer and water holding agents onto coated wire mesh. Creat is used with an anchored sprayed concrete ("Creat") grillage. The grillage, formed using sprayed concrete, is anchored to the slope using 200 mm long x 8 mm diameter mild steel pegs. The Strip technique uses the sprayed mix and mesh but also includes fertilizer bags. The General technique comprises the sprayed mix and mesh only.

These are relatively new techniques to Hong Kong that originated in Japan where they have been quite widely used. The only example of these techniques visited was at Smithfield Road (Plates 14k and 14l), where they were used on part of 2 newly constructed soil cut slopes.

Details of this technique can be obtained from the local agent (see Appendix E). It is claimed that the Creat technique can be applied to steep rock or sprayed concrete slopes and landslide scars up to 85°. The Strip technique can be used on soil slopes up to 85° and on rock and sprayed concrete slopes up to 70°. The General technique can be used on soil slopes up to 70°.

The sprayed mix is designed to allow ready establishment of grass in harsh environments. The grass is guaranteed for 5 years, during which time the local agent will ensure the grasses are properly watered. It is not clear what happens after this time, and it is anticipated that regular watering would be required in perpetuity to maintain the effect. The technique does not seem applicable to larger shrubs and trees due to the limited soil volume in which these plants could find support.

This technique may provide a useful means of grassing steep rock slopes or slopes that have a sprayed concrete covering. However, the long-term establishment of the grass is considered problematic with dry season browning and die-back having to be considered. These hydromulching techniques appear to be gaining support in Hong Kong with four government departments using the techniques in forthcoming contracts. These new sites and the existing sites should continue to be observed critically since it would seem that these modified hydromulching techniques offer some prospect of successful long term greening of slopes.

(7) "ON" Method. A proprietary method comprising a sprayed mix of grass seeds, fertilizer, resin and soil mix with Portland cement onto plastic coated wire mesh. Although this technique has been available in Hong Kong since the 1980s there are only about 8 examples. It is difficult to assess why this technique has been neglected in Hong Kong compared with Japan and Taiwan. It seems that the cement binding agent is less resilient than the resin of the Toyo-mulching techniques and is liable to crack and lose its integrity. Details of this technique can be obtained from the local agent (see Appendix E). The review visited one slope at Tregunter Path. The technique can be applied to steep soil, rock or sprayed concrete slopes. The technique was applied (in 1984) to a 60° dominantly rock cut about 10 m high with an undulating surface profile. Close inspection found that most of the sprayed mix had been washed out leaving just the wire mesh (Plate 14m). The slope has since been colonised by self-seeded groundcover plants and trees and it is therefore difficult to assess how successful the method has been.

(8) Geogrid Reinforced Slope with Vegetative Cover. This comprises layers of compacted fill embedded with geogrid reinforcement that can be wrapped over at the face of the slope. The technique can be applied to fill embankments or can be used to create a soil reinforced block, similar to a gravity wall, at the toe/face of a cut slope. Slope gradients of up to 80° can be treated using this method. Vegetation can be established on the slope face and the technique has been referred to as a "Green Wall". Geogrids are proprietary products. To use a geogrid in permanent reinforced fill construction in Hong Kong requires certification by GEO. Those slopes visited were in recreational settings, namely Hong Kong Park and Fanling Golf Club.

Altogether 4 slopes were visited; these were constructed about 10 years ago with gradients between about 50° and 60° and are about 5 m to 9 m in height. An inspection of the slopes found them to be in a satisfactory condition. Sufficient vegetative cover had established on the slopes to hide almost completely the geogrid reinforcement.

Originally the slopes at the Golf Club had been hydroseeded with grass but the slopes have since been colonised by creepers and other local groundcover plants. The overall visual effect is considered successful, with the slopes blending in with the local landscape (Plate 12i).

The technique allows vegetation to be established on a steep face and as such is suitable for sites that are highly constrained and that have a high visual importance, for example, it has been used in Hong Kong Park (Plate 14n). There are limitations on the planting of shrubs and trees in pits in the surface as these can grow to disrupt the facing geogrid causing localised surface erosion. Brush layering, or hydroseeding with grass are the preferred methods of establishing such vegetation types. The use of mixed plant species, such as grasses and shrubs planted on to the face would increase the overall appearance of the slope. This slope design provides an ideal environment for establishing vegetation on steep slopes but unfortunately, its use in Hong Kong has been limited. This is perhaps attributed to lack of local experience and the need for a relatively high level of construction supervision.

(9) Reinforced Fill Structure with Facing Panels. This comprises layers of compacted fill embedded with tensile reinforcing elements connected to facing panels. Reinforced fill structures are proprietary products. These products need to be certified by GEO before being used in Hong Kong.

The commonly used arrangement for panels is a vertical wall or a stepped-back wall. There are a number of vertical wall examples in Hong Kong but fewer stepped-back walls. An example of a stepped-backed wall is at Hong Kong University of Science and Technology, Sai Kung (Plate 14o). The stepped-back effect was considered visually very successful with the vegetation from the planters effectively screening most of the facing panels.

Reinforced fill structures can provide a high quality aesthetic finish. The technique is relatively expensive compared to other slope techniques due to overseas manufacture and the high level of construction supervision required, particularly to ensure that the compaction of the backfill is to a satisfactory standard, see GCO (1989). However reinforced fill structures can be considerably cheaper in comparison to retaining structures, such as reinforced concrete walls.

(10) Berm Planters. Longitudinal walled planters generally less than 1 m deep by up to 3 m wide. Mainly found on slopes with hard surface covers. Berm planters were present on 17 slopes visited, for example western approach to Cheung Ching Tunnel and southern approach to Ting Kau Bridge, Tsing Yi (Plate 14p).

Berm planters were considered to mitigate some of the visual impact of a hard surfaced slope. It was however noted that because of the limited space available in the planter larger screening plant species could not be planted. Also, the straight lines formed by the berms tended to enforce the artificial appearance of the slope. That said, on some of the newer slopes visited it is likely that the artificial look of the berms should gradually be screened by plant growth.

Berms planters are generally inaccessible for horticultural maintenance and where irrigation systems are not installed there is the possibility of plants dying off. Plant species need to be of sufficient resilience to withstand the harsh conditions in berm planters. Self clinging, climbing plants tend to be the most effective plant type for such planters.

(11) Toe Planters. Either continuous longitudinal or isolated walled planter at the slope toe. Increasingly used to provide street level screening of particularly hard surfaced slopes. Plants used include climbers, groundcover, shrubs and more commonly trees. Altogether 43 of the slopes visited had toe planters. Several good examples of toe planters were visited at Victoria Road and the Chinese University (Plate 14q).

When viewed close-up or at medium range toe planters provide an effective screening of the slope. For large-scale slopes, when viewed at long-range the toe planters are generally too small to provide an effective screen.

Toe planters with large trees and self-clinging climbing plants were considered one of the most effective methods of mitigating the impact of steep rock cut slopes and retaining walls.

(12) Hanging Planters. Generally placed at mid-height on a retaining wall, the hanger consists of a trough containing soil and plants. The planter is usually formed as an integral part of the structure of the wall. There are relatively few examples of hanging planters, the review included 2 walls where hanging planters were used.

On particularly tall retaining walls, the planter provides an effective means of introducing vegetation at mid-height to screen the wall face (Plate 14r). Plants typically used include creepers and trailers, which need to be hardy, given the relatively harsh growing conditions in the planter.

(13) Surface Pit Planters. Soil filled circular void formed in hard surfacing and used to plant creepers. General arrangement of pits is typically 150 mm diameter at 3 m centres (CED, 1994). Because this technique has only been introduced in the last few years the review did not find any slopes where there was extensive creeper establishment from surface planter pits. However, several slopes were visited where such planting had recently been undertaken, such as Sai Sha Road and Wong Nai Chung Gap Road.

The introduction of surface pit planters is considered to offer considerable potential for greening of hard surfaced soil cut slopes. There would appear to be scope to vary pit dimensions and spacing to suit site conditions and to maximise the greening effect. Recent work in this regard has been undertaken by HyD. The current spacing of pits of about 3 m would appear to be too conservative, given that for example the spacing used in Grasscrete, a comparable technique, is less than 400 mm.

(14) Vegetation on Rock Cut Slopes. The review included 8 vegetated rock slopes with slope angles that ranged from 35° to 70°, most notable amongst these is the Turret Hill ex-quarry site, Shatin (Plate 14s).

At the Turret Hill site, the final rock faces were designed with the provision of ledges and crevices to retain soil and moisture for vegetation (Appendix B). The rock face comprises about 20 m high benches at about 50° separated by 5 m wide berms. Planting on the slope was carried out by individually siting plants and soil in ledges and crevices, with the addition of hydroseeding. The result is considered visually pleasing and is one of the few successfully vegetated rock slopes seen in the review.

The remaining vegetated rock slopes that were visited appear to have been the result of self-seeding of plants with varying degrees of success. Where rock ledges were of reasonable size and seepage was present, vegetation establishment provided a reasonable screening of the rock face.

The adoption of a rough rock profile is considered a key element in creating a successful habitat for the establishment of vegetation. The routine practise of smooth wall blasting cannot provide sufficient roughness for vegetation establishment and furthermore, the pattern of pre-split holes tends to give an artificial appearance to the slope (Plate 14t).

(15) Vegetation on Rock Fill. In the past few years rehabilitation of ex-quarries has resulted in the need for methods of establishing vegetation over rock fill slopes. The review included rehabilitation works at the Shek O (Plate 14u) and Lam Tei (Plate 14v) Quarries. At both sites rehabilitation works aim to provide a re-vegetated landform that will mitigate the visual impact in the shortest possible time and encourage a self-sustaining ecosystem that will provide a natural environment for future land use.

The rehabilitation works at both sites are using a similar technique of rock fill "scree" slopes formed at 35° overlaid with geotextile/granular filter, soil and an erosion control mat on the surface. Planting at the Lam Tei site (Appendix B) is confined to the 5 m wide level berms situated at 15 m intervals between 70° rock slopes and includes tree whips, shrubs and climbers. The results are reported as encouraging but a significant amount of exposed rock is clearly visible above the berms.

At Shek O quarry, the planting strategy is to remove the steep quarry face, comprising 10 m high, 70° rock cut face separated by 5 m wide benches and replace it with a generally 35° planted soil slope. The planting includes a range of grasses and whip trees which are tolerant to dry conditions. Work was only recently begun at the site and it will take a number of years to determine the success of the scheme.

(16) Existing Mature Trees on Slopes and Walls. More of a landscape mitigation measure than a landscape treatment, the retention of existing mature vegetation, including mature trees, can be a vital element in the successful visual appearance of upgraded slopes. The review included 23 features in this group. Trees were found growing on nearly all types of features at inclinations up to vertical and on most materials including rock and masonry. Existing mature trees on soil slopes with hard surfacing are generally retained using tree rings, see below (No. 18).

A few examples of trees on rock slopes were observed. Behind the Duchess of Kent Children's Hospital, Sandy Bay, are good examples of existing mature and recently self-seeded trees, notably *Ficus microcarpa* and *Ficus variegata*, growing on a rock slope (Plate 14w).

The review also visited 4 walls with existing mature trees. Eastern Street, Mid-Levels is a good example of a masonry wall with mature existing trees, *Ficus microcarpa*, that has recently been upgraded using a skin wall with masonry cladding. The profile of the skin wall was varied to avoid the existing trees (Plate 14x). Nearby, at Northcote College, Bonham Road recent upgrading of a masonry wall with mature trees used small toe buttresses which avoided harming tree roots (Plate 14y).

Tree species can grow successfully on slopes formed predominantly of rock and at inclinations up to the vertical. Trees provide a focal viewpoint and are visually pleasing especially wall trees. For routine slopeworks in rock, however, tree planting is not practical because the smooth wall finish left by pre-split blasting provides few opportunities for trees to establish. There is also the risk of tree toppling.

(17) Street Trees. Street trees provide a useful means of screening a slope and provide a green roadside corridor. The review included 2 examples of slopes with street trees, at Lee Nam Road, Ap Lei Chau and Sui Wo Road, Kowloon (Plate 14z). As with toe planters,

this method is considered to offer considerable potential for landscape and visual mitigation of slope works.

(18) Tree Rings. Concrete ring formed generally of sprayed concrete around existing trees on slopes with hard surface covers. Tree rings were found on 27 of the slopes in the review, which comprise about 25% of all the hard surfaced slopes visited. The range of slope angles for cut slopes was between about 40° and 85° and for fill slopes between about 20° and 35°.

Where the hard surfacing is used, tree rings may provide an effective means of preserving existing trees (Plate 14aa). The technique is adaptable as it can be used at almost any inclination. However, the limitations of the technique must be appreciated. In a significant number of cases the trees died, and where only a few trees were retained, their preservation on a hard surfaced slope did little to mitigate the visual impact of the slope. According to TDD's experience the successful use of tree rings in hard surfaces is very limited. In general the trees so retained slowly die through poisoning from the alkali shotcrete, or soil compaction, or lack of soil aeration and/ or soil moisture. Furthermore, there is no maintenance authority at present likely to go back to remove the dead stumps from the tree rings and replant with new trees. Preservation of trees by this method should only be a last resort, since it is usually not truly preservation but a slow death.

8. CONCLUSIONS

This report presents the findings of a number of reviews and guidance on the aesthetic design of man-made slopes in Hong Kong. The following are the main conclusions.

(a) An opinion survey of a sample of 57 geotechnical engineers showed that about 60% of respondents considered that existing slope landscape guidelines are insufficient (Appendix C).

(b) An opinion survey of 26 landscape architects showed that most respondents considered that landscaping was not given sufficient priority in the slope design process (Appendix C).

(c) An inspection of some 200 slopes in Hong Kong was undertaken to assess the landscape treatments used and their effectiveness. Numerous treatments have been used in Hong Kong but the majority of slopes use only a few types of landscape treatment.

(d) Sprayed concrete cover was used on about 50% of the slopes inspected in this study.

(e) Landscape maintenance is generally neglected. Where this is the case, surface drainage is frequently blocked. This can have a profound effect on stability during heavy rainstorms.

(f) Landscape issues have often been neglected in design consideration particularly in older slopes, but public/media pressure has resulted in increased attention to landscaping at early design stages. Landscaping professionals should be involved at every stage: design, construction and maintenance.

(g) Vegetative treatments are now available that can be used at relatively steep slope angles (Table 12).

(h) On a number of slopes inspected, self-seeded local plant species were observed.

(i) The use of grillages anchored with soil nails is considered to offer potential for vegetation establishment on steep slopes.

(j) Based on the findings of the inspections, currently the most effective and practical landscape treatments for steep slopes are:
- the use of toe planters, especially with screening trees and climbers,
- the use of climbers in surface pit planters and,
- modification of slope geometry to allow retention of rock faces and existing vegetation.

9. RECOMMENDATIONS

The findings of the review have indicated an increasing awareness of the visual appearance of slopes amongst the geotechnical profession. Many areas for improvement are currently being investigated by GEO, and continued improvement in the visual appearance of slopes is expected. The integration of landscape issues into current practice in slopeworks will require administrative changes. These administrative changes would require:

9.1 Administrative Recommendations

(a) The production of a slope landscape guide directed at engineers. The existing landscape guidelines used by engineers are contained within many disparate documents. A single illustrative guidance document for engineers would be an effective means of promulgating landscaping ideas. Relevant existing documentation would require to be redrafted.

(b) Training of project engineers and managers to understand the need to consider the visual appearance of slopes, and familiarisation with the techniques available.

(c) Commitment at senior level to achieving better visual appearances to slopes is also essential and, in particular, emphasis on the involvement of landscape professionals within the slope design and construction process.

(d) Landscape objectives, and how they are to be achieved, should be clearly stated at the outset of the design process, say at the Option Assessment Stage in the LPM process. The Government should establish a system for the design and implementation of work in respect to the landscape objectives. This could possibly be in the form of auditing by GEO staff, supported by landscaping professionals in the Government, as part of the slope maintenance audits being carried out.

(e) Instigation of a procedure of reviewing slope designs to ensure the best landscaping treatment possible is achieved within the geotechnical constraints of the site.

(f) There is no point in designing and constructing an aesthetically attractive landscape treatment unless there is a commitment from all concerned to carry out short and long term maintenance. Neglected vegetated landscape treatments can have a deleterious effect on slope stability and their untidy appearance discredits vegetative treatments. Training of project and maintenance engineers and managers in the importance of landscape maintenance is recommended. A system for long-term landscape maintenance for slopes should be set up.

(g) An audit of maintenance of landscape works by a suitably qualified person, similar to routine maintenance, should be undertaken. This would include a measure of the health of plants (in respect to pest and fungal attack), the composition of species (in relation to the planting intentions, and signs of damage or disturbance). Information should be forwarded to the Department(s) with responsibility for management and maintenance for further action.

9.2 Technical Recommendations

Numerous techniques for improvement of the appearance of slopes may be viable in Hong Kong. It is recommended that:

(a) Where possible, rock should be retained in the finished surface. Natural rock surfaces without sprayed concrete, rock bolts and artificial supports can be aesthetically pleasing. Controlled blasting to produce a multi-faceted face with pockets large enough to support planting has been used successfully in Hong Kong and is recommended.

(b) If artificial supports are necessary it is suggested that smaller scale elements blend in to the rock face more readily than large scale features such as buttresses.

(c) Slope infrastructure such as access ladders, drainage channels, catchpits and sand traps must be as visually unobtrusive as possible. This can be achieved by pigmentation of the concrete to match the slope face, recessing and hiding the infrastructure if possible or designing drainage channels which follow natural contours. Straight lines and sharp angles should be avoided.

(d) If irrigation is part of a vegetated landscape requirements then it must be done or the treatment will fail.

(e) It is recommended that topsoil should be stockpiled for later use in landscape restoration.

(f) Vegetative treatment, in particular hydromulching techniques, which can be used at relatively steep angles (Table 12) should be trialled or where in use should be observed and assessed.

(g) Self-seeding of local plant species requires further investigation to investigate its potential.

(h) The use of grillages anchored with soil nails is considered to offer potential for vegetation establishment on steep slopes and should be trialled. Grillages have been widely and successfully used in Japan but little literature in English is available.

(i) The selection and installation of plants in a vegetative treatment must be under the supervision of a specialist.

(j) When erosion control matting is specified, planting into pits below the mat should be arranged so that cutting of the matting is minimised. Manufacturers specification must be rigorously followed.

(k) Bio-engineering techniques. There is an increasing number of bio-engineering techniques available (Appendices D and E). Several of these techniques have been used to create relatively steep natural "green walls" using vegetation as reinforcement. It is proposed that trials are undertaken to establish the suitablility of techniques and plants for Hong Kong.

9.3 Proposals for Further Work

There are a number of areas, noted above, where further research is warranted. These have been prioritised on the basis of their immediate practical use.

	Area	Trial Objectives	Possible Funding/ Management	Design/ Implementation
1	Use of Tree Seeds	Trials to test the use of seeds of different tree species in hydroseeding mixes	Government / CED, TDD or HyD	consultant / term contractor
2	Planting of Native Species	Further, systematic trials of native tree and shrub species to determine the optimum technique for the establishment of a self-sustaining native woodland	Government / CED, TDD or HyD	consultant / term contractor
3	Bio-engineering techniques	Trials to test the geotechnical engineering and landscape potential of bio-engineering techniques known to be used elsewhere in the world, e.g. green walls, bush layering, live pole, fascines, etc.	Government / CED, TDD or HyD	consultant / term contractor
4	Proprietary products	Trials to demonstrate the effectiveness of new proprietary products (various new products)	Suppliers / CED, TDD or HyD	consultant / suppliers

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